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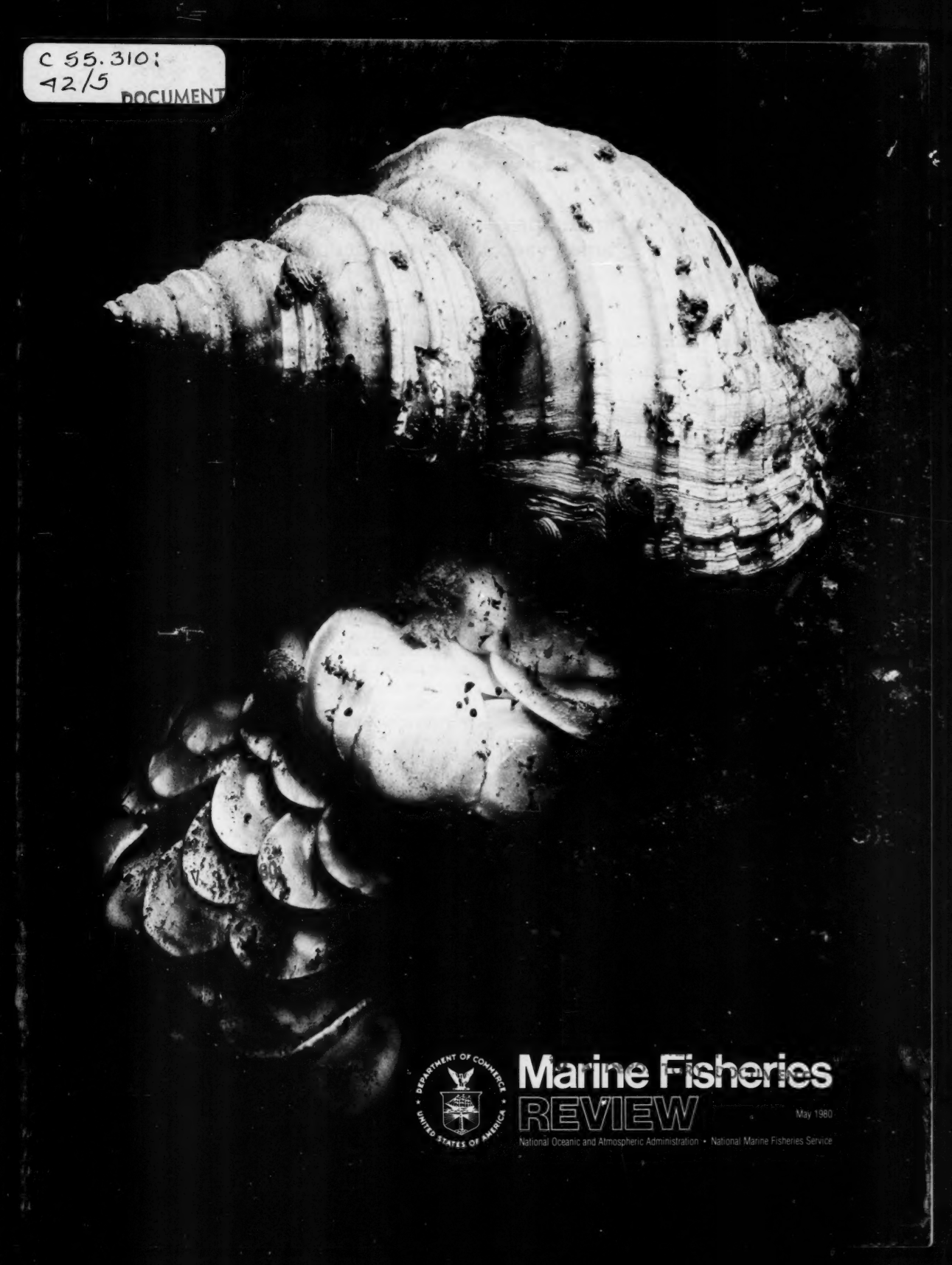

Marine Fisheries REVIEW

May 1980

National Oceanic and Atmospheric Administration • National Marine Fisheries Service

Marine Fisheries REVIEW

On the cover: *Neptunea lyrata*, laying eggs, was photographed in Alaska's Auke Bay by Lou Barr, then with the NMFS Auke Bay Fisheries Laboratory, Auke Bay, AK 99821. See the article beginning on page 15.

Articles		*May 1980*
Implications of Transplantations to Aquaculture and Ecosystems	*H. Rosenthal*	1
The Snail Resource of the Eastern Bering Sea and Its Fishery	*Richard A. MacIntosh*	15
Groundfish Monitoring in Sponge-Coral Areas Off the Southeastern United States	*H. Powles* and *C. A. Barans*	21
Departments		*Vol. 42, No. 5*
NOAA/NMFS Developments	*U.S. Fish Catch Up in 1978, NOAA Aids Atlantic Salmon Restoration*, and Oceanographer *Visits China*	36
Foreign Fishery Developments	*World Fishery Trade Told for 1978* and *Chilean Fishing License Regulations*	38
Publications	*New NMFS Scientific Reports, Marine Toxins, Advances in Marine Biology*, and *Gulf of California Reef Fishes*	39

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Implications of Transplantations to Aquaculture and Ecosystems

H. ROSENTHAL

ABSTRACT–Increasing aquaculture activities occur primarily in areas where support and supply for the developing industry are available, e.g., close to main shipping routes and harbors. Because intensive aquaculture operations often provide ideal conditions for initial establishment of exotic species, the chances for transfer of nonindigenous species increase. Diseases have spread rapidly through multiple transfer of major candidate species for aquaculture. An overview is given of important deleterious side effects accompanying transplantation of aquatic organisms. Well-documented examples on general pathways involved in transplantation of harmful and unwanted species are presented. Problems associated with control measures and regulations are discussed.

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Introduction

Since the appearance of life on the earth, organisms have populated new regions, and the advent of man has accelerated the process.

Transplantation of aquatic organisms is a very common activity today. Belief that such introductions are beneficial is the driving force for such activities. This paper reviews some of the well-documented examples of the deleterious side effects accompanying transplantation to demonstrate the need for preventive measures on an international basis.

Implications to Aquaculture and Ecosystems

Transfer by Sea Traffic

Introductions of nonindigenous species via sea traffic (i.e., ship hulls, ballast tanks) are important to aquaculture development in coastal regions for the following reasons: 1) Increasing speed for modern seagoing vessels has not proved a barrier for transfaunation (Allen, 1953); 2) increasing traffic density may provide a continual infusion of foreign species until a critical population size is reached, thus enhancing the chances for successful establishment; 3) intensive aquaculture operations often offer excellent conditions for the initial establishment of potential invaders; and 4) increasing aquaculture activities occur primarily in areas where support and supply for this development branch of industry are already available and where socio-economic needs can be met at least partially by already established industries (Hansen, 1974; Landis, 1971).

There is not much we can do to reduce continuous transfer of organisms on ship hulls and in ballast tanks. Since expansion of the aquaculture industry will most likely take place close to developed transportation systems (e.g., harbors and shipping routes), the opportunity for establishment of exotic organisms is increased. Therein lies the danger.

Although the introduction of the Australian barnacle, *Elminius modestus*, into European waters has not become a serious problem to any aquaculture operation, it is a classical example to demonstrate: 1) the capability of a potential invader to utilize ship hulls as long-distance carriers, and 2) how rapid local spread by other pathways may be ensured.

This barnacle was first recorded at the end of the Second World War from Chichester Harbour, U.K. (Bishop, 1947). It spread rapidly, first to the Netherlands (1947), to The Federal Republic of Germany (1953), and then to Denmark (1961) (Den Hartog, 1953; Barnes and Barnes, 1960; Powell, 1960; Kühl, 1963 a, b). Crisp and Southward (1959) calculated its range extension as 30 km/year. Kühl (1963 b) explained its rapid spread along the German coast as due not only to the high density of sea traffic between harbors, but also to the activity of mussel farmers in transferring seed mussels to different growing areas.

It may be assumed that isolated populations at small fishing harbors along the coast were initiated by fishing boats acting as vectors. Barnes and Barnes (1960) pointed out that this type of dispersal need not involve traffic between harbors; it requires only that boats fish in waters containing abundant larval populations. Wherever *E. modestus* is abundant, it seems to affect adversely the growth of planktonic larvae of other benthic animals that breed in summer, including larvae of the oyster *Ostrea edulis*.

Several species of crabs have been introduced via ballast tanks. The Chinese mitten crab, *Eriocheir sinensis*, was transferred to The Federal Republic of Germany in 1910, to Belgium in 1912, and it reached the coast of Denmark in the twenties. During the

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thirties, this species occurred in the Baltic Sea and was recorded from the Finnish coast in 1933. It also appeared in Dutch and French waters during the thirties (Hoestlandt, 1959; Karppinen and Kairasuo, 1961). In The Federal Republic of Germany, fishing gear and catches were damaged severely and in the Netherlands, damage to dikes was reported.

After more than 60 years of continuous spread that might have made net cage culture in inland waters almost impossible, the Chinese mitten crab stock has diminished. This crab is no longer considered a serious problem, at least in The Federal Republic of Germany and the Netherlands. New population explosions as well as the establishment of this species in other regions cannot, however, be excluded. Nepszy and Leach (1973) reported a first observation in North America. Three specimens were taken in Lake Erie in 1973. Another record of its presence is the collection of a single individual at Windsor, Ontario, in 1965. Presumably this crab was carried to Lake Erie in ballast tanks, as Peters and Panning (1933) considered it may have been carried from Europe.

Ships are probably the principal agent for transferring exotic marine algae. Walford and Wicklund (1973) mention a number of marine algae now found outside their natural range that may have been distributed by ships. For example *Asparagopsis armata*, native to Australia, Tasmania, and New Zealand, has now spread to the British Isles, western Europe, and the Mediterranean. *Fucus inflatus*, a subarctic species, is considered to have been brought by fishing vessels to the Göteborg region in Sweden, where in some places it is the dominant *Fucus* species, and has been found south at least as far as Copenhagen. The green alga *Codium fragile tomentosoides*, presumably native to Japanese waters, has become distributed around the world perhaps in ballast water of ships or perhaps with seed oysters. It threatens many valuable beds of clams and oysters and has already smothered many of them. Not much is known about the ecological implications of such introductions but the effect of *Codium* should be noted. The Japanese seaweed *Sargassum muticum* was accidentally introduced and is now well established along the south coast of England. Eradication of *Sargassum* by hand gathering was attempted initially, but although several hundred tons were removed by this method during 1976, the practice has been largely abandoned as ineffective (Franklin, 1977).

The amphipod *Gammarus tigrinus*, endemic to the east coast of North America (Bousfield, 1958), has been introduced into European waters, possibly in bilge water or ballast tanks (Schmitz, 1960; Bassindale, 1946; Hynes, 1954, 1955; Hynes et al, 1960; Nijssen and Stock, 1966). This species also spread successfully after it had been deliberately introduced in the rivers Weser and Werra in The Federal Republic of Germany. A continuous extension of range of this alien amphipod is reported by Pinkster and Stock (1967) and Smit (1974). Initial mass development caused alarm in the Netherlands and The Federal Republic of Germany where it was reported to cause damage to bownets and fish caught in them. No further negative effects on fisheries due to its introduction have been reported, but this gammarid has now largely replaced the former gammarid fauna of many lake districts in the Netherlands (Chambers, 1973).

There are increasing numbers of reported transfers of fouling organisms via ships to different seas (Walford and Wicklund, 1973). This is of special importance to coastal shellfish and finfish pen culture as fouling organisms may cause serious operational problems. Since its introduction, the barnacle *Balanus improvisus*, first described from North and South America, may have damaged oysters in Lake Hamana and the pearl culture industry along the Japanese coast (Kawahara, 1963).

A number of other translocated fouling organisms may prove to be harmful to aquaculture operations. *Mytilus edulis galloprovincialis* Lamarck, probably transferred on ship hulls from the Mediterranean, caused considerable damage to Japanese oyster culture operations in the vicinity of Ondo near Hiroshima due to competition for space and food. The reduction of the long-term average yield has been estimated to reach approximately 64 percent for the 1973 growing season (Arakawa, 1974). *Balanus eburneus* from the Atlantic coast of North America has been transferred to European and Japanese waters (Bishop, 1951; Utinomi, 1966). *Balanus amphitrite amphitrite*, native to the tropical Pacific, has become common in Japan (Utinomi, 1960). A hydroid, *Hydroides norvegica*, was introduced to New Zealand from Australia. Other fouling organisms introduced into Australasian waters include: *Bugula flahellata*, a bryozoan from the Atlantic and Mediterranean; a British nudibranch, *Thecacera pennigera*; a hydroid, *Bougainvillia ramosu*; and a massive form of the encrusting *Zoovia schizoporella unicornis* (Allen, 1953).

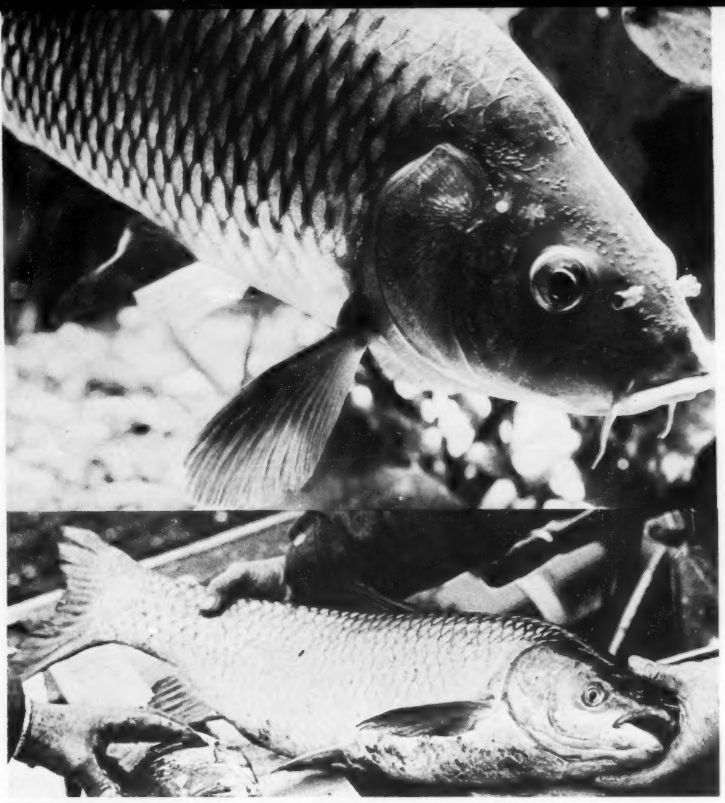
Purposeful Transplantations

Several classical examples of deliberate introductions exist. The history of tilapia, *Tilapia mossambica*, common carp, *Cyprinus carpio*, and grass carp, *Ctenopharyngodon idella*, shows that fish considered successful aquaculture candidates in one region are not necessarily successful in others.

Tilapia

An important stimulus to fish culture development in Southeast Asia, as well as in other areas, was the introduction of the exotic *Tilapia mossambica* and other *Tilapia* species (Bardach et al., 1972). After many successful introductions, it was observed—first in the Philippines—that several species of fish such as *Scatophagus argus, Mugil* spp., and *Teuthis* spp., which are often stocked in milkfish, *Chanos chanos*, ponds to provide added income, became stunted in the presence of *Tilapia* and therefore fetched a low price (Pillai, 1972). Rabanal and Hosillos (1957) regarded *Tilapia* as one of the worst pests in ponds in the Philippines, causing injuries to milkfish fingerlings.

Tilapia melanopleura was introduced into Mauritius in 1956 and kept under controlled conditions. Some specimens accidentally escaped into adjacent waters where they have harmed



Classical examples of deliberate introductions include the common carp, *Cyprinus carpio* (top); and grass carp, *Ctenopharyngodon idella* (bottom). Photos courtesy of the U.S. Fish and Wildlife Service and the Missouri Department of Conservation respectively.

indigenous flora and fauna (George, 1975). Introduction of *Tilapia* has had many positive results, but it is obvious in many countries that culture of other species of higher market value is considerably hindered because of difficulties in controlling the population growth of introduced *Tilapia*. Even if the maximum standing crop is very high it will consist largely of great numbers of small "trash" fish. Monosexculture is one way out of the dilemma but unfortunately it cannot be applied everywhere.

Other problems associated with successful transplantations may arise under local conditions. The most serious example reported in the literature is that of pond construction for *Tilapia* culture in Puerto Rico, which has increased the habitat for the fluke responsible for *Schistosomiasis* and its intermediate snail host (Courtenay et al, 1974; Odum, 1974).

Common Carp

The common carp, native to east and Southeast Asia, was introduced into Italy and Greece during Roman times (Thienemann, 1950). It has since been distributed throughout Europe, introduced into Australia (Vooren, 1972) and into North America (Cole, 1905; Dymond, 1955; McCrimmon, 1968). The Federal Government of the United States actively promoted public acceptance of this species near the end of the 19th century. Intentional introductions into Canadian waters progressed during the same period. The less desirable aspects of the carp were not recognized in either country, and early warnings of the likely consequences of its establishment in American waters were overlooked. Both carp and goldfish introduced into New York State in the 1830's later escaped into the Hudson River and multiplied with spectacular rapidity. As early as 1883, an increase of carp in Lake Erie caused a drastic decrease in the wild celery and wild rice beds of the lake. This was typical of the situation which was to develop in literally hundreds of North American waters within a few years (see McCrimmon, 1968; Chambers, 1904; Cole, 1905). In the first annual report of the Fisheries Branch of the Province of Ontario for 1899, it was mentioned that carp feed on the spawn of other fish, although later authors could not show clearly appreciable egg predation in all regions (Ensign, 1960; Harlan and Speaker, 1956). In another later report it was noted ". . . that carp had become so abundant in Burlington Bay at Hamilton that they had driven native catfish and other coarse fish out of the inlets" (McCrimmon, 1968). Since the beginning of this century, carp have been considered nuisances wherever found in North America. Carp are still extending their distribution in Canada and have migrated into the western parts of the country, where they are more destructive, virtually eliminating aquatic vegetation in several areas of Manitoba. Carp have failed to receive public acclaim as a sport fish in North America, but have now become established in 46 states of the United States. Their habits of uprooting vegetation and muddying water have resulted in the expenditure of millions of dollars on control and eradication programs, none of which has been very successful (Laycock, 1966; Courtney and Robins, 1975).

Common carp also have been introduced into Mauritius where they escaped into Lake Mellawaine (Murno, 1967), possibly competing with *Clarias gariepinus* for chironomid larvae, and displacing it (George, 1975).

Carp have failed to establish themselves as self-sustaining populations where stocked in several natural waters in Egypt and Uganda. George (1975) attributed this to heavy predation of Nile perch, *Lates nilotica*, and other predatory fishes. On the other hand, this species is now well established in Ethiopia, where no adverse effects on indigenous fauna are reported. However, George (1975) citing Jackson

(1960) listed the main reasons why most legislation in Africa now forbids any introduction or transplantation of live carp:

"(a) Carp have a wide ecological tolerance and can thrive when conditions become minimal for other fish, thus hastening the elimination of other species where they live.

(b) They destroy the eggs of other species, destroy the vegetation in their habitats, to the extent often of eliminating all vegetal growth and, by constant rooting in the substrate, muddy the water, and cause salt to accumulate, destroying insect and other benthic life."

This destructive sequence of events may not always be realized in cases where escaped fish from carp farms establish themselves in natural waters, but it is almost impossible to predict which of the above mentioned effects will finally dominate.

Grass Carp

The introduction of grass carp, *Ctenopharyngodon idella*, for biological control of aquatic vegetation has become common in many countries. There is considerable disagreement over the beneficial features of this species. Lachner et al. (1970) reported on early warnings against further introduction into the United States by members of the American Fisheries Society and the American Society of Ichthyologists and Herpetologists, assuming that destruction of aquatic vegetation could cause ecological damage to the native fauna (fishes, invertebrates, and waterfowl). Grass carp have not only been introduced into the Mississippi watershed, but they are said to be in more than 40 states at present, at least in private hands or in confined waters. So far, the consequences are unknown, aside from the fact that grass carp will pull up emergent cattails (*Typha*).

In North America, and in many areas, aquatic weeds are themselves exotic species. At least some of them have spread via aquarium fish importation. In Florida, biological weed control was started by introducing another exotic, the blue tilapia, *Tilapia aurea*. Since its introduction in 1961 it has become so abundant that some streams are devoid of most vegetation and nearly all their native fishes. Nevertheless, not having learned from this lesson, the introduction of grass carp into Florida is probably merely a matter of time.

Courtenay and Robins (1975) discussed the possible ecological implications of experiments with grass carp in Oregon and Florida. Grass carp removed the aquatic plant *Hydrilla* from a pond in 1 year and destroyed spawning areas for native centrarchid fishes.

In the lower Mississippi Valley the grass carp may affect rice production, as pointed out by Courtenay and Robins (1972). Furthermore, statements made by a Chinese committee on freshwater fish raising are cited by Roberts et al. (1973): "*Ctenopharyngodon* are highly destructive of rice plants and must be kept out of paddies," thus implying that this fish may cause an economic disaster in rice-growing areas.

Salmonids

Salmonids have been introduced around the world and in most cases these introductions have proved to be remarkably successful. George (1975) considers the introduction of trout into Africa as not having seriously affected the indigenous fishes because its distribution is restricted to high, cold, upland streams, where economically important indigenous species are seldom resident. However, extermination of local fish such as *Amphylius hargeri* due to trout introduction is known in Rhodesia. Jackson (1960) reported that freshwater mullets, *Trachyistoma euronotus*, and kurpers, *Sandelia capensis*, have disappeared since trout and black basses (*Micropterus*) were introduced into South Africa.

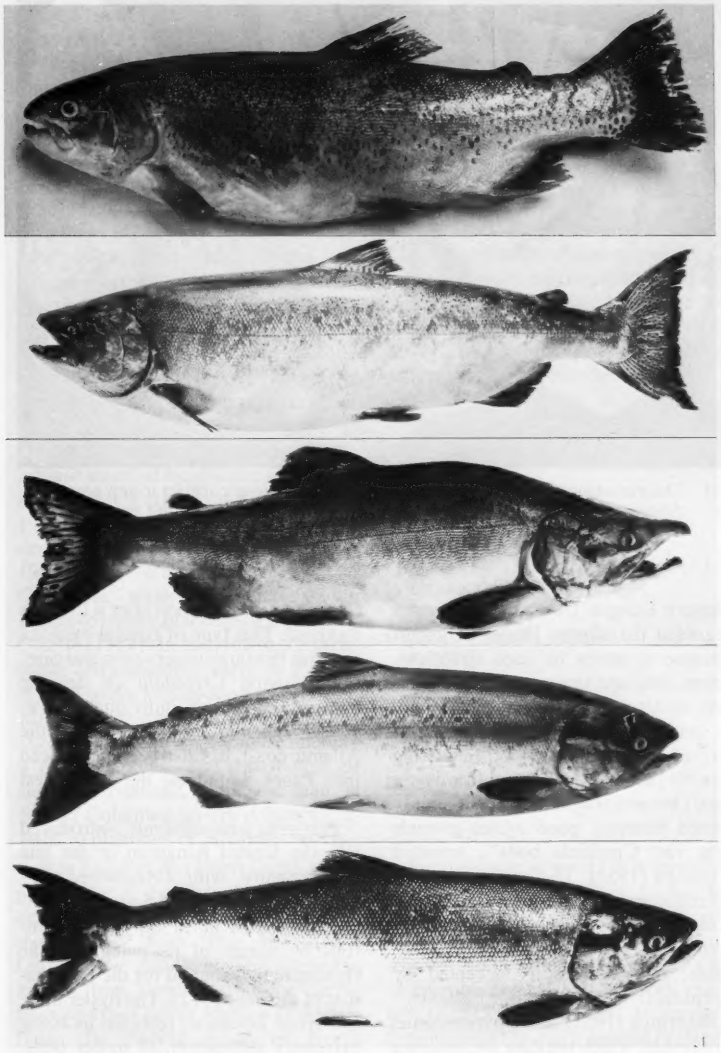
A classical example of deleterious side effects due to the introduction of a highly suitable aquaculture candidate, the rainbow trout, *Salmo gairdneri*, is that of its establishment in Lake Titicaca in South America during the Second World War. From an economic viewpoint this introduction proved to be successful. In the early sixties, between 100 and 410 tons of trout were landed annually. Meanwhile cyprinodont species (*Orestias*) suffered from heavy predation by trout. Because they were no longer abundant, rainbow trout thenceforth took insects as their predominant prey. In the meantime, some *Orestias* species have been eliminated from the native fauna (Villwock, 1963, 1966). *Orestias* also suffered from sporozoan infections, introduced via rainbow trout (Villwock, 1972).

Release of Pacific salmon from hatchery produced stocks into creeks and rivers other than their native ones is a common practice throughout the North Pacific region. In many instances returns within the recipient tributary did not exhibit the expected success. As Ricker (1972) summarized, chinook transfers made over great distances very often resulted in poor returns or at least into such straying from the stream of release. For example, Columbia chinooks of spring stock transplanted to "fall" streams had very poor success in locating their adopted tributaries even after entering the main river in large numbers, and in fact many went right past the tributary of rearing and release and on up the river. Pink salmon transplanted to the Kola peninsula returned in large numbers in 1960, but principally to streams other than those in which they were planted. According to Ricker (1972) there exists some evidence for a hereditary component in the guiding mechanism as well as in time of return. Thus it can not be excluded that extended releases of stocks for aquaculture purposes may have led to some destruction of genetic programs of local wild stocks.

Problems associated with transplantation of salmonids involve numerous diseases, which have caused considerable concern to aquaculturists. This subject is dealt with in a later section.

Other Fishes

Some further examples are worth mentioning. The mosquitofish or top minnow, *Gambusia affinis*, native to the southern Mississippi Basin, has been introduced into many tropical areas, and has become a strong com-



Many salmonids have been introduced throughout the world. From top to bottom are the rainbow trout, *Salmo gairdneri*; chinook salmon, *Oncorhynchus tshawytscha*; pink salmon, *Oncorhynchus gorbuscha*; coho salmon, *Oncorhynchus kisutch*; and sockeye salmon, *Oncorhynchus nerka*.

petitor of common carp in the Transcaucasus and central Asia (Nikolski, 1961; Vooren, 1972). At least the younger stages of carp show retarded growth where they coexist with *Gambusia* in ponds. Courtenay and Robins (1973) noted, in many regions where *Gambusia* have been introduced, that existing native fishes were as effective mosquito destroyers as *Gambusia*, and the documented result of these introductions has been the destruction of many small native fish species. George (1975) stressed that great care should be exercised in the introduction of *Gambusia* into new ecosystems. Introduction of this species for larvicidal purposes has been recorded from various African countries but it could not establish itself in habitats where there are predatory fish such as *Lates niloticus* and *Clarias* sp.

Nikolski (1961) also mentioned that perch (*Perca fluviatilis*) may form dense populations of small stunted fish when introduced into water bodies without native competitors. Additionally, in restricted areas they may displace species belonging to lower trophic levels. This was found to be true in a reservoir in Belgium, where brown trout, *Salmo trutta*, wild carp, and minnows disappeared after introduction of the perch around 1900 (Thienemann, 1950). Vooren (1972) listed five introductions that stand out as cases where obvious detrimental effects on indigenous species have been recorded: the pike (*Esox lucius*) in Ireland; *Perca fluviatilis* in Belgium; largemouth blackbass, *Micropterus salmoides*, and the sunfish, *Lepomis auratus*, in northern Italy; and *Gambusia affinis* in the U.S.S.R. The destructive pressure on indigenous species has been noted with the organisms which constitute their prey. Furthermore, in some local waters in the Netherlands, *Micropterus* and *Lepomis* have already caused a decline in the abundance of some indigenous piscivorous fishes.

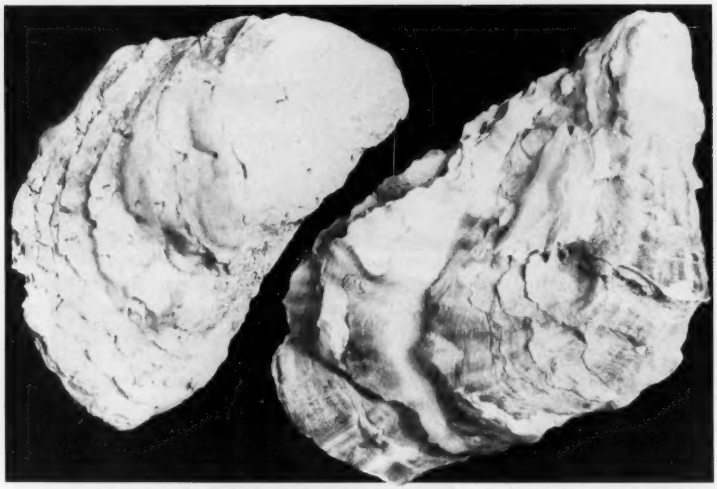
Vooren (1972) concluded that ". . . successful introductions of large high-level predators have often recreational value, but from a commercial fishery point of view their value is usually small or very local. . . . Where there exists a commercial fishery for species that occupy a lower trophic level, the establishment of a foreign piscivorous predator may be detrimental to this fishery. . . ."

In Japan, elvers of the European eel, *Anguilla anguilla*, were imported for several years to meet fish farm requirements for seed. So far success has been limited because of the high mortality and disease susceptibility of European elvers in Japanese waters. Eel farms in Japan can make a profit only when the survival rate is about 70 percent from local species and about 30 percent for imported species.

Crayfish

Recent introductions of nonindigenous crayfish species into many parts of the world are well documented. The red swamp crayfish, *Procambarus clarkii*, was imported to Kenya lakes by well-meaning people around 1967. It was hoped that the crayfish would reduce the population of a snail carrying a stage of bilharzia disease. Unfortunately, the newcomer multiplied rapidly, reducing bottom vegetation to such an extent that young fish became easily available to predation. As a consequence, fish populations declined drastically (Unestam, 1976). During the first half of this century the same species has been transferred from the United States to Japan, probably to serve as forage for other economically important species. As the result, crayfish are now considered a pest to the rice crop. On Hawaii, introduction of *Colocacia esculenta* has become a great threat to the taro crop (Unestam, 1974).

Crayfish, which often feed on diseased fish, are considered as possible vectors in spreading introduced fish diseases, such as infectious pancreatic necrosis. As has been pointed out by Unestam (1974), a certificate from veterinary laboratories stating freedom from dangerous parasites in examined crayfish is of little value since no general methods exist which can detect specialized parasitic bacteria, fungi, and viruses.



The transplanting of oysters has also introduced other exotic species to new areas. Above are the American oyster, *Crassostrea virginica* (left), and the Pacific oyster, *Crassostrea gigas*.

Accidental Introductions of Other Species

Oysters

One example, representative of many, is the accidental introduction of the slipper limpet, *Crepidula fornicata*. Native to the Atlantic coast of North America, it was carried to northern Europe and to the Pacific. Stocking of the American oyster, *Ostrea virginica*, in English beds at the end of the 19th century led to the establishment of the unwelcome limpet on the Kent and Essex coasts. Korringa (1942) explained how *Crepidula* succeeded in extending its range in coastal waters of western Europe. Dutch oyster farmers regarded the slipper limpet as a pest because it settles on seed collectors, grows fast, and tends to crowd out the tiny oyster spat on cockle shells (used as spat collectors at the time *Crepidula* arrived in Dutch waters). "Scattering [cockle] shells as collectors [for oyster seed] became unprofitable as it simply turned formerly good oyster grounds into vast Crepidula beds", reported Korringa (1951). The oystermen were forced to revert to the old-fashioned tile collectors, expensive but efficient in offering only a rough surface for attachment, one not readily accepted by *Crepidula*.

Korringa (1951) also provides other arguments which indicate the nuisance of this invader. If present in great numbers on an oyster bed, *Crepidula* deposits so much silt and soft mud that the beds are rendered unsuitable for oyster planting. Further, it ingests oyster larvae during their pelagic lives, thus impairing production of oyster spat.

In later years, Dutch oyster farmers used thin, brittle mussel shells as oyster spat collectors. Young *Crepidula* may settle on mussel shells as do young oysters. Thin mussel shells soon break away leaving the young oyster free, but *Crepidula* dies off soon after it loses its foothold. This type of control measure requires thorough supervision and care, not allowing *Crepidula* to develop harmful chains of individuals. *Crepidula fornicata*, originating from the Atlantic coast, has also been introduced into Puget Sound on the U.S. west coast.

Petricola pholadiformis, introduced into the United Kingdom in the late 19th century with *Crassostrea virginica* from the United States, has colonized several north European countries by means of its pelagic larvae (International Council for the Exploration of the Sea, 1972). The oyster drill, *Ocenebra japonica*, reported as being extremely destructive to oyster beds, was introduced with oyster shipments from Japan to the United States. *Ostrea edulis*, transplanted to South Africa, was responsible for the introduction there of the European gastropod *Ocenebra erinacea* (Hancock, 1960). *Mytilicola orientalis*, also introduced with oyster seed from Japan to the U.S. Pacific coast (Chew et al., 1964), has been shown to cause pathological changes in the gut of the Pacific oyster, *Crassostrea gigas*.

How *Mytilicola intestinalis* spread to

northern Europe from its original home in the Mediterranean is not known. In some areas this may have been entirely accidental and in others the result of some deliberate introductions (International Council for the Exploration of the Sea, 1972). In Great Britain, the species was first recorded in 1947 from the Northumberland coast (Hepper, 1955). *Mytilicola intestinalis* was also introduced into west Scotland, possibly with oysters from France in the late sixties, where it is now affecting mussels (International Council for the Exploration of the Sea, 1972).

Plantings of Japanese oysters along the west coast of North America are responsible for the introduction of another oyster drill, *Purpura clovigera* (Quayle, 1964 a, b) as well as for the establishment of the oyster *Crassostrea rivularis* (Walford and Wicklund, 1973) and the bay mussels *Modiolus demissus* and *M. senhousei* (Hanna, 1966). Some further invaders of British Columbia waters associated with Japanese oyster plantings are listed by Quayle (1969). In addition to a coelenterate (*Dradumene*), there is a worm (*Pseudostylochus estreophagus*), a mollusk (*Batillaria zonalis*), and a seaweed (*Sargassum muticum*), to mention only a few examples. The distribution of *Battilaria cumingi*, a Japanese snail, in British Columbia waters is directly related to plantings of Japanese oysters.

Van Engel et al. (1966) found a high percentage of the crab, *Eurypanopeus depressus*, from the Virginia coast parasitized with the sacculinid *Loxothylacus panopaei*. This species is known from Xanthids from the Caribbean and the Gulf of Mexico as well as from the Pacific coast of North America, but has not been reported from the Atlantic coast. The authors considered this as a clear example of an introduced species: "Since 1960 when oyster stocks in lower Chesapeake Bay were reduced by a disease called 'MSX', a substantial quantity of live oysters has been imported from the Gulf of Mexico each year in refrigerated trucks. This practice is new and is a highly probable source of sacculinid-infected mud crabs."

At least one exotic estuarine fish, a goby (*Acanthogobius flavimanus*), has been established on the Pacific coast of North America. Brittan et al. (1963) believed that the explosive spread of this fish in the San Francisco Bay region, was a result of the introduction of a few specimens accompanying the transport of culture organisms from Japan.

Diseases

At present eight major communicable fish diseases are potentially dangerous to freshwater finfish culture in Europe; Thompson et al. (1973) showed the following distribution of their reported incidence in 22 European countries in 1972.

Disease	*Countries*
Whirling disease	16
Furunculosis	15
Viral haemorrhagic septicemia (VHS)	14
Infectious dropsy of cyprinids (IDC)	13
Ulcerative dermal necrosis (UDN)	7
Infectious pancreatic necrosis (IPN)	7
Swim bladder inflammation of cyprinids (SBI)	6
Infectious haematopoietic necrosis (IHN)	0

Furunculosis in trout, first reported from Bavaria in 1894, is known to occur in most of Europe and North America, but was probably native to western North America, because it was in epizootiological balance with rainbow trout, *Salmo gairdneri*. In Europe, furunculosis became a serious problem in brown trout, *Salmo trutta*, after rainbow trout had been introduced. The first outbreak of this disease in Sweden in 1951 might also be attributed to an import of infected fish eggs (Nybelin, 1951).

Furunculosis is now present almost everywhere salmonids are cultured, except in Australia and New Zealand (Snieszko, 1973). The disease is caused by a bacterium *Aeromonas salmonicida*. Some authors believe that this pathogen is closely associated with its host, but others claim that it reproduces freely in nature. Christensen (1972) mentioned transmission of this disease by infected eggs and by fish with latent infections, which act as reservoirs.

Infectious pancreatic necrosis (IPN), which affects several salmonids, was first recorded in the United States and later in France, Denmark, Sweden, Italy, Scotland, and Japan. It is caused by a virus and prophylaxis is its only effective control. The results of Moewus-Kobb (1965) indicate that marine fish cell lines will support the multiplication of IPN-virus in vitro, and that the virus survives in several species in vivo, but without proof of multiplication. This is an important observation with regard to rainbow trout culture in coastal waters. Where viruses are concerned, fish culture in most cases is restricted to measures for avoidance, and propagation of specific-pathogen-free stocks.

In the case of IPN, Wolf (1972: 316) stated: "It should not be assumed that virus will always result in high mortality among exposed populations. There are considerable observational data which suggest that host and pathogen reach some biological balance in a restricted system such as a hatchery which propagates a particular lineage of carrier trout. The danger of such a situation is that it fosters complacency in management. Because the virus may not be considered serious, infected stock could be distributed to places where virus may not be present and this could certainly result in further spread of the virus."

Only the young fry and the juvenile fish suffer from the clinical form of IPN, whereas larger fish are rarely killed off but become virus carriers (Scherrer, 1973). This might be one reason why IPN is now distributed to almost all countries involved in salmonid farming. Sano (1973) demonstrated experimentally that IPN could easily be transferred to two species of Pacific salmon (*Oncorhynchus* spp.) when virus-contaminated trout are released from culture ponds to natural water bodies.

Infectious dropsy of cyprinids (IDC)

occurred in Czechoslovakia in 1929 and 1930 when common carp, *Cyprinus carpio*, fry were imported from Yugoslavia. A further rapid spread occurred during the Second World War, when stock carp were transported from one European country to another, without proper health control (Havelka, 1973). As a consequence, carp culture in Europe was affected severely for more than a decade and the disease spread not only to most pond farms but also to some natural waters.

Liebmann (1973) reported rapid spread of swim bladder inflammation of cyprinids (SBI) since the early fifties; in former years this disease was only sporadically recorded. He stated that the disease, which apparently originated in the U.S.S.R., spread westward to Austria, Czechoslovakia, The Federal Republic of Germany, Hungary, and Poland. Fish without symptoms can act as carriers.

Another virus disease, infectious haematopoietic necrosis (IHN), is believed to have occurred in sockeye salmon, *Oncorhynchus nerka*, on the west coast of North America since 1952. It also affects *O. tshawytscha* and rainbow trout. It recently has spread into the states of Minnesota, Washington, Montana, South Dakota, Idaho, and Oregon, where it affects rainbow trout. Transplantation of diseased fish or eggs from infected brood stocks is considered as the continuous supply (Amend et al., 1973).

Survival of "Egtved virus" the causative agent of viral haemorrhagic septicemia (VHS), for a prolonged period in frozen trout has been reported. So far, transfer of this virus due to importation of frozen trout and introduction of live salmonid eggs from Europe to North America has not occurred (Ghittino, 1973).

Whirling disease is found in 14 salmonid species and the grayling (*Thymallus*). It is caused by the sporozoan, *Myxosoma cerebralis*, first described in southern Germany in 1903 (Christensen, 1972), and is now present in almost all areas where salmonids are cultured, including the U.S.S.R., continental Europe, British Isles, Republic of Korea, South Africa, and North America (Bogdanova, 1973). It also occurs in seven species in natural waters. The very pronounced species difference in susceptibility of salmonids to *M. cerebralis* is well documented. "The hypothesis has been put forward that the invasion is indigenous in the European brown trout and therefore balanced, while the American rainbow trout and brook trout not coming from the same biotope are more susceptible" (Christensen, 1973). Thus, infected fish, or fish transported in contaminated water must have been transferred to North America. Viable spores can also be transferred in frozen trout.

Two cases of whirling disease causing substantial economic losses in the United States may be mentioned as typical examples. One trout grower was completely out of production for almost 3 years due to whirling disease transfer from his supplier. Another trout hatchery supplemented its well water supply with water from a nearby river system. Unfortunately the river had been stocked previously with trout carriers of whirling disease, which led to a total loss of the hatchery stock. Thompson et al. (1973) stated that the direct cost to the agency administering the publicly-owned hatchery was between US$250,000 and $300,000, and the loss to the angling fishery the hatchery would have supported is no less than four times the direct loss.

Disease organisms pathogenic to man may also be transferred in the water accompanying imported aquatic species. More than 100 million fish were imported into the United States in 1972, together with a minimum of about 11.3 million liters of water. There exists a great danger of introducing *Schistosomiasis* (bilharzia) in regions with suitable conditions. This has already happened in some areas of the Caribbean (Odum, 1974). Regarding the import of live aquatic animals from tropical regions, rapid air transport increases the survival chances of waterborne stages of flukes and other pathogens such as *Salmonella* and *Vibrio cholera* (Courtenay and Robins, 1975).

Janssen (1970) has pointed out that most bacterial pathogens of fish belong to the genera *Aeromonas*, *Pseudomonas*, and *Vibrio*, which include species also pathogenic to man. Chronic granulomatous lesions of the extremities are caused by *Mycobacterium ballnei*, sometimes found in swimming pools, aquariums, or tropical fish tanks. According to Oppenheimer (1962), Middlebrook (1965), and Janssen (1970), this organism is identical to *Mycobacterium marinus*, a pathogen of fresh and saltwater fish. *Mycobacterium tuberculosis* innoculated into carp multiply and maintain their virulence for years (Griffith, 1930). *Vibrio parahemolyticus* is one of the few fish-borne human pathogens which has been found to be identical to a pathogen occurring in oysters (*Crassostrea virginica*) and blue crab, *Callinectes sapidus* (Krantz et al., 1969). This suggests the organism is widespread in its marine distribution, and that the practice of cooking seafood may be the chief factor in limiting this fish-borne human disease among western nations (Janssen, 1970). Janssen and Meyers (1968) reported that fish may be actively infected in nature by a variety of human pathogens associated with contaminated water. Therefore, transfer of human pathogens with the fish trade remains a danger.

Fish Parasites

Transfer of fishes is much more effective in successful transplantation of parasites than would be expected from the literature. Usually only a few cases are reported due to a lack of experts available for immediate and reliable identification. Hoffman (1970) listed several intercontinental disseminations of fish parasites: "At least 48 species (5 protozoa, 31 monogenea, 5 digenea, 3 nematodes, 1 acanthocephalan, 3 copepods) of freshwater fish parasites have become established on other continents through the transfer of infected live and frozen fish." Five of these monogenetic trematodes reported from Israel were carried by *Tilapia* imported from Africa. One might expect an equal number of cases reported from other areas where *Tilapia* has been introduced, sometimes even more intensively. Few parasitologists have looked

into this problem. It is impossible therefore to evaluate the ecological implications of massive transfer of diseased organisms. Merely because there are as yet no records does not mean that disruptions of existing ecosystems have not occurred.

Recently, new cases of disease transfer have been noted in the literature. Several authors cite grass carp, *Ctenopharyngodon idella*, as a notorious carrier of parasites and diseases (Cross, 1969; Courtenay and Robins, 1975). *Hemiophrys*, an exotic ciliate protozoan, is believed to have been introduced into Missouri with grass carp, its host (Courtenay et al., 1974). Bardach et al (1972) reported that the tapeworm, *Bothriocephalus gowkongensis*, introduced into U.S.S.R. with grass carp imported from China, has become a serious problem in European cyprinids. Kezić et al. (1975) detected this parasite for the first time in Croatia, Yugoslavia, during 1972, about 8 years after the transfer of grass carp to that country. Also in The Federal Republic of Germany *Bothriocephalus* has spread to many carp farms, causing some mortality in heavily infested specimens.

Argulus pillucides, first recorded in Egypt on mirror carp, *Cyprinus carpio*, in 1952, seems to have been transmitted with introduced specimens from France (George, 1975).

Highly migratory species may be considered as subsequent invaders of regions other than those where introduced, and straying individuals may also be regarded as potential disease carriers. The sturgeons, *Acipenser güldenstädti* and *A. baeri*, which were transplanted into the Gulf of Riga by the U.S.S.R., have been caught along the Swedish coast. Pacific salmon (*Oncorhynchus*) introduced by the U.S.S.R. into the river systems draining into the Barents Sea have been caught repeatedly in Norway, Iceland, and Scotland.

Shulman (1954) reported that introduced species constitute a focus of infestation for the local fauna, as happened when the sturgeon *Acipenser stellatus* was transplanted to the Aral Sea. A monogenetic trematode of the gills (*Nitzschia sturionis*), transmitted from it to the local *Acipenser nudiventris*, caused massive mortality among the local species of the Aral Sea.

Infestation of acipenserid fishes by parasites of cyprinids and salmonids has been observed in a number of cases. This raises the important question of the nature of specificity in fish parasites. It is well known that under laboratory conditions the strict specificity of many parasites is lost. This indication that changed environmental conditions may change host specificity can be demonstrated by many examples. The first intermediate host of the liver fluke in Europe is *Limnea truncatula*. This parasite will not develop in other representatives of the genus *Limnea* even when experimentally inoculated, but in other areas (North America, Australia), to which the liver fluke has been introduced, other species of *Limnea* and even another genus of snails will serve as intermediate hosts for this parasite.

Soviet scientists studying whitefish transplanted from one lake system to another provided a clear example of the breakdown of host specificity. Shulman (1954) reported that larval *Unionicola*, normally parasitic in the mollusks *Unio* and *Anodonta*, had infested the introduced whitefish. He considered two circumstances worthy of attention: 1) the larvae of *Unionicola* had not established themselves on a native whitefish but on an introduced one, and 2) this larva resembled *Unionicola crassipes*, which is not a normal parasite of this genus of host, i.e., a form which has less stable specificity. The relaxation of specificity here is connected with the action of the external environment on one link or the other (or on both together) of the "parasite-host" system.

Fishes

Borisova (1972) listed ten species of fish (*Opsonichtys uncirostris amurensis, Pseudorasboa parva, Pseudogobio rivularis, Hemibarbus maenlatus, Hemiculter lencisculus, H. eigenmanni, Rhodeus sericeus, Perceottus glehni, Hypselaotris swinhonis,* and *Rhinogobius similus*) accidentally introduced with grass and silver carp into fish farms near Tashkent (Uzbekistan) since 1961. All of these small nonexploited species originated from the Yangtse River. Nevertheless, the natural range of these species includes the northern and southern districts of China, as well as Korea, Japan, and the Amur Basin. These fishes first became established in a fish farm, but about 3 years later most of them penetrated through canals into adjacent rivers, where they partially displaced indigenous species and formed new biocoenotic structures. They showed a more rapid growth rate and a higher fecundity under their new conditions than populations of the Far East. These changes were connected with alterations in feeding habits; they not only utilized a wide range of planktonic and benthic food organisms but also made maximum use of artificial feeds at the fish farm. Because of their small size, it is almost impossible to eliminate these fish from ponds by gill nets.

San Feliu (1973) reported the accidental introduction of *Micropterus salmoides* into a Spanish lagoon of the Mediterranean coast around 1956. The fish has become acclimatized and is now rather abundant. It is not known whether native species are affected.

Other Introductions

Live Transport and Storage

Another source of unintentional introduction of a species is the live transport and storage of aquatic animals prior to sale—a common business in many countries. Lobsters and crayfish are usually sold alive. For many years the Netherlands has stored lobsters obtained from Norway, Scotland, and Ireland in ponds in Zeeland. In Great Britain, many thousands of American lobsters, *Homarus americanus*, have been imported from North America since 1968. Mussels from Ireland are held in Wales, and prior to sale to consumers the same species is quite commonly held in coastal "basins" in France after importation from Spain.

Hoffman (1970) provided a table showing the species of marine animals imported live for consumption from six continental European countries, the

British Isles and Canada to 10 European countries and the U.S.S.R. Ten species of molluscs, four species of crustacea, and two species of eel (*Anguilla anguilla* and *A. rostrata*) are involved. This listing covers a very restricted area, but as such activities occur throughout the world, the high potential for transfer of nonindigenous species parallel to such activities is obvious.

Ornamental Fish Trade

The pet fish industry provides another example of the high risk involved in escape of exotic species kept and raised in fish farms. The most spectacular recent experience is with the walking catfish, *Clarias batrachus*, from Asia, which escaped from a fish farm in Florida and became established. Since the mid-sixties, it has distributed itself over more than 8,750 km² in 10 counties of Florida. The range of this exotic may extend into other states within the next few years. The threat to native fishes is thought to be serious (Courtenay and Miley, 1975).

Courtenay et al. (1974) and Courtenay and Robins (1975) have reviewed the introductions of exotic fishes into Florida. Forty-two exotic species and several hybrids were found in waters of Florida during the early seventies. Of these, 24 species and 5 hybrids are considered to be established permanently. Most of these introductions involved escapes from pet fish farms. Waterways in the vicinity of pet fish farms often contain more species of exotic fishes than native forms, and existing ecosystems have been altered considerably. Besides ecological disruption in isolated areas, so far only four species have expanded their range to create considerable concern: *Clarias batrachus, Cichlasoma bimaculatum, Tilapia aurea,* and *Belonesox belizanus*.

Of about 65 fish species introduced into Arizona (some confined to reservoirs), only 29 are food and game fishes in the United States.

In Papua, New Guinea, where an estimated 12,000 aquarium fish are imported annually, two aquarium fish

The American eel, *Anguilla rostrata*, is one of many species often transported live around the world. Photo by Lloyd Poissenot, Louisiana Department of Wildlife and Fisheries.

species have become established (West, 1973), although six species account for about 50 percent of ornamental fish imports. The guppy, *Lebistes reticulatus* (Peters), was first observed in 1967 in the Port Moresby region from where it spread to nearby swamp areas of the Laloki River system. The species has spread further since—as could be expected from experience gained in Indonesia, where it competes for food with more valuable native fish (Schuster, 1950). The second species found recently in shallow back waters is the threespot gourami, *Trichogaster trichopterus trichopterus* (Pallas), where it dominates in numbers both native fish species and the deliberately introduced *Tilapia mossambica*.

With the exception of a few species, the supply of saltwater aquarium fish will not be derived by egg-to-egg culture but will be obtained by transfer of collected specimens from natural sources for many years to come. For the same reasons, regulations are needed not only for import-export of live species but also for local transfer of specimens within the natural distributional range of a species.

With respect to the export of ornamental fishes, Conroy (1975) described the situation of disease control in prophylactic measures for South America as follows: "The present situation . . . is that the ornamental fish shippers place a blind faith in the use of substances such as acriflavine and methylene blue, or on imported commercial products, usually without any understanding of the nature of the disease(s) or of the correct method of using such products."

Bacterial diseases as well as endo- and ectoparasitic infections are extremely common among ornamental fishes in many countries. Establishment of harmful parasites due to continuous and indiscriminate transfer of their hosts in other areas cannot be excluded. The worldwide transfer of live ornamental fish has reached astonishing proportions; the trade still has to be considered as an expanding industry. For example, in 1974, Colombia alone exported over 12 million ornamental fish (124 species) to about 17 countries in Europe, Asia, and the Americas. Peru, in 1971, exported about 13 million ornamental fish (72 species) to about all countries in these regions.

Conroy (1975) described the danger of introduction of diseases by common export practice for ornamental fish as follows: " . . . many exporters ship their fish in water taken from ponds, streams and rivers of questionable biological and bacteriological quality. The principal danger lies in the practice, common in the trade, for the water in which incoming fish have been received to be disposed of in an untreated state through channels or conduits in the floor. Although in urban areas this effluent usually enters the public sewage system, in rural areas it is common for the effluent to enter directly into the open ditches or streams. In the event that organisms, potentially pathogenic to fish or aquatic plants, should be present in the incoming water, these organisms could thereby gain access to open waters in the country of destination. . . While it holds true that several of the more common fish parasites are also known to occur naturally in regions other than those to which the imported fish are native (e.g., *Saprolegnia* spp.,

Ichthyophthirius multifiliis, Argulus spp.), the danger is the possibility of 'exotic' strains of these parasites being introduced and, in this way, causing epizootics among members of the native fish fauna of the waters into which they were accidentally introduced."

From the ornamental fish trade in the United States it is reported that about 60 percent of all imported tropical fishes die within 30 days, and that most of the fishes have ichthyophthiriasis or fungus infections. Thompson et al. (1973) mentioned two arguments supporting the opinion that transferred diseased fish may also lead to the establishment of pathogens in new environments: 1) Host specificity is uncertain in new environments, and 2) new and more virulent strains of pathogenic bacteria may develop or be imported into the new environment.

Fish Disease Control Problems

Thompson et al. (1973) in reviewing national and international measures for the control of the major communicable fish diseases of Europe and North America, listed five major reasons for delayed or incomplete control of fish diseases: 1) Lack of veterinary skills, 2) fear of adverse economic effects, 3) lack of a central registry and reporting service, 4) lack of research, diagnostic techniques, and quarantine methods, and 5) administrative and enforcement shortcomings and difficulties, including lack of interest by governmental organizations, lack of trained customs inspectors, and inadequate legal authority. These reasons may be applied almost equally to the entire problem of control of introductions and transplantations of aquatic organisms by widening the sense of their statements, e.g., "and lack of ecological skills" might be added to the first reason.

One of the problems involved in a consistent inspection of the international fish trade is demonstrated by the availability of piranhas, which are still displayed by dealers as aquarium fishes in Florida. Concern among biologists about the establishment of these dangerous species in southern Florida's fresh waters, where environmental conditions have permitted the establishment of other exotic tropical species, has led to the prohibition of the importation of piranhas into the United States. Nevertheless, they are still available on the tropical fish market under a variety of Spanish, Portuguese, and native names. Moe (1964) explained the difficulty of controlling importation: "Most of the piranhas that are imported are young juveniles that find their way into the shipments of other characins. Young piranhas are so similar in shape and color to many of their vegetarian relatives that only an experienced ichthyologist can distinguish them. They often are not recognized until they reach the tanks or outdoor ponds of the wholesaler". How easy it is for them to slip in when the certificates are dealing with species of a "clean list" only.

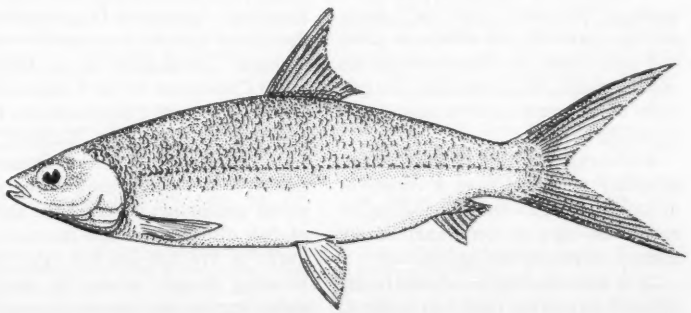
Another problem is that of seed export and import of some of the important aquaculture candidates: Mullet (*Mugil*) and milkfish (*Chanos chanos*) fry and elvers. It is almost impossible to completely eliminate fry or postlarvae of unwanted species (predators, competitors) from shipments.

Considering the world trade in ornamental fish, Axelrod (1973) described how the risk of transferring major communicable fish diseases and parasites can be reduced considerably by improved storing, transporting, and receiving of shipments.

Other gaps still remain. An important one with respect to fish disease is demonstrated by an example of common handling procedure, when transporting fish by truck over long distances in central Europe. Under present transport conditions, water will be exchanged each 24 hours or at least after 1,500 km of travel. Often tank water is discharged into creeks, lakes, or rivers, without disinfection, increasing the opportunity for disease transmittal. As another example, German imports of live trout for consumption are often maintained in farm ponds for several days. After processing, the resulting waste parts are usually fed to fish in adjacent ponds, thus increasing the risk of disease transfer not only for the cultivated stock but also to the native fauna.

International regulations for the control of transplantations of nonindigenous species are also required. Many species, once introduced into an area, may extend their range far across the borders of the country where initially released. Considerable effort on an international basis is necessary if we are to cope with the rapid increase in worldwide transplantation of exotics.

For more than 25 years, the United States Fish and Wildlife Service has sponsored the U.S. Foreign Game Introduction Program. In its early years, Bump (1951) viewed the general problem of the introduction of exotics: "Nor



Milkfish, *Chanos chanos*.

has any method been so blindly applied and consistently mishandled. Although it is one of the earliest techniques to be applied, few who have used it have bothered to learn by experience, and no one has as yet formulated a set of guiding principles and practices."

Regier (1968) discussed the introduction of exotics under these different concepts: 1) Vacant niche, 2) trophic level, and 3) competition. We may cite Regier directly: "I think what is often meant by vacant niche is that certain possible trophic levels in the community haven't enough organisms in them for the good of the system as a whole. The good of the system of course is almost invariably seen in terms of its potential production of what man sees to be an immediate benefit. *We choose exotics on the basis of what they can do for us and not primarily on what they can do for the nonhuman system*."

With regard to utilization of trophic levels, we may encounter much more complex systems with fish than with other organisms of lower systematic categories. Courtenay and Robins (1973) proposed some minimal methods for considering introductions into U.S. waters in order to stop disastrous imports. These recommendations are summarized here:

1) Reasons for seeking an introduction should be clearly stated and demonstrated.

2) Within the qualifications set under 1), a search for possible contenders should be made, and a list prepared of those fishes that appear most likely to succeed, with the favorable and unfavorable aspects of each species noted.

3) Preliminary assessment should be made of possible impact on aquatic ecology generally, the effects on game and food fishes, on waterfowl and on aquatic plants, the catchability and edibility of the species, and the implication to public health.

4) Assessment should involve appropriate personnel from a variety of agencies or organizations, and not be restricted only to personnel of the agency proposing the introduction.

5) A research program should be developed to test the import in confined waters from which escape is prevented.

6) Evaluation of the results should be made by a panel of representatives from all involved agencies.

7) With favorable reviews the release should be effected.

As emphasized by Courtenay and Robins (1973), "No importation of a species for release purpose is so urgent that its biological implications should not be severely reviewed by a broad panel of experts from representative government and public agencies." Most importantly, we should "seek to hold the line as regards man's unnecessary destruction in those areas where a native community is still flourishing" (Regier, 1968).

But even aside from this biological/esthetical viewpoint, a major concern regarding the present exponential increase of worldwide transplantation activities, is that elimination of introduced pests is extremely costly and frequently impossible. It is true that many transplantations in the past, even without previous assessment of possible side effects, have proved to be extremely successful. The one-sided negative view of this paper is, therefore, intended to stimulate an in-depth discussion of the problems involved.

Under any circumstances it certainly appears that the transplantations of exotic aquatic organisms, at least as far as those made directly by man are concerned, need a much higher degree of control than now exists. The reasons have been outlined and illustrated with well-documented examples. It now remains for more concrete action to be taken.

A forward step was taken, with respect to one aspect of this aim, when the Food and Agriculture Organization of the United Nations convened the Government Consultation on an International Convention for the Control of the Spread of Major Communicable Fish Diseases, at Aviemore, Scotland, in 1974 (Food and Agriculture Organization, 1974). Action toward this proposed convention covering the spread of fish diseases through international traffic in live fish and fish eggs, now awaiting further action by governments, can be regarded as encouraging. Others should follow soon and Druehl's statement made in 1972 still holds: "Action is required now if we are to curb further disruption of the marine biosphere."

Summary and Conclusions

Transfer of aquatic species usually occurs along one of four pathways: 1) Translocation of a species beyond its natural range by sea traffic; 2) Purposeful transplantation of organisms; the target, introduction into new areas; 3) Accidental introduction in connection with transfer of other species; or 4) Escape of organisms transferred for purposes other than actual introduction.

Detrimental effects of the introduction of exotic species include: 1) Reduced growth and development of the introduced forms because of less favorable environmental conditions than those found in their indigenous areas; 2) Population explosion of the introduced species, leading to competition with and eventual elimination of native species; 3) Concomitant introduction of new pests, diseases, and parasites harmful to resident species; and 4) Destructive activities of the introduced species affecting other fields of economic interest.

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The Snail Resource of the Eastern Bering Sea and Its Fishery

RICHARD A. MacINTOSH

Buccinum sp., photographed in Alaska's Auke Bay by Lou Barr, then with the NMFS Auke Bay Fisheries Laboratory, Northwest and Alaska Fisheries Center, Auke Bay, AK 99821.

ABSTRACT–A trawl survey in the eastern Bering Sea outlined the distribution and relative abundance of several large snails of commercial importance. Snails made up 6.6 percent of the invertebrate biomass with members of the genus Neptunea *being most abundant. These snails lack a larval stage and are facultative predators and scavengers. Japan has harvested snails in the area since at least 1971. Reported catch rates in pots ranged from 0.9 to 4.0 kg/pot and total Japanese catch has varied from 404 to 3,574 t of edible meat per year. The United States has the vessel capacity to enter the fishery but probably will not do so until there is a large increase in the value of snail products.*

The Alaskan continental shelf is an area of vast fishery resources. Fish and crab resources are well known and have long been exploited by many fishing nations; potential resources, like eastern Bering Sea snails, are virtually unknown. Several species of large snails occur in relatively high abundance in Alaskan waters and offer considerable fisheries potential.

Japan has harvested snails in the eastern Bering Sea since the early 1970's and there is potential for the development of a U.S. domestic fishery as well. This report presents information about the Japanese fishery in the eastern Bering Sea, life history characteristics for the principal snail species, and discusses the potentiality for U.S. participation in the harvest of this unique shellfish resource.

The Snail Resource and Its Composition

During the summer and fall of 1975, the Northwest and Alaska Fisheries Center of the National Marine Fisheries Service (NMFS) conducted a comprehensive trawl survey over 566,000 km² (218,600 miles²) of the eastern Bering Sea shelf and upper slope (Fig. 1). This survey was designed to identify principal demersal fish and shellfish communities of the eastern Bering Sea which could be affected by development of continental shelf energy sources. Data on fish and epibenthic invertebrates were gathered from several hundred locations with a modified 400-mesh eastern otter trawl. The resulting data offered significant insight into the population and biological characteristics of numerous species of snails.

Gastropods made up 1.7 percent of the total biomass and 6.6 percent of the invertebrate biomass in the survey area (Pereyra et al.[1]).

Distribution of snails throughout the area is patchy, with the areas of highest concentration also supporting a high biomass of fish and epibenthic invertebrates. Snail biomass in some areas exceeded 3,000 kg/km² (17,000 pounds/nmi²); however, if the trawl is not effective at catching species of snails that sometimes burrow into the substrate, then the biomass may actually be much higher.

About 15 species of large (>5 cm) snails are common in the eastern Bering Sea (Table 1). Members of the genus *Neptunea* are by far the most abundant in terms of both numbers and biomass. The Pribilof neptune, *N. pribiloffensis*, (Fig. 2), is probably the most abundant *Neptunea; N. lyrata, N. ventricosa,* and *N. heros* (Fig. 2) are also very

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[1]Pereyra, W. T., J. E. Reeves, and R. G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. Processed rep., 619 p.

Table 1.—Scientific names of large snails taken in the eastern Bering Sea during the 1975 trawl survey of the NMFS Northwest and Alaska Fisheries Center.

Beringius beringii (Middendorf, 1849)
Buccinum angulossum Gray, 1839
B. plectrum Stimpson, 1865
B. polare Gray, 1839
B. scalariforme Möller, 1842
Clinopegma magna (Dall, 1875)
Fusitriton oregonensis (Redfield, 1848)
Neptunea heros (Gray, 1850)
N. lyrata (Gmelin, 1791)
N. pribiloffensis (Dall, 1919)
N. ventricosa (Gmelin, 1791)
Plicifusus kroeyeri Möller, 1842)
Pyrulofusus deformis (Reeve, 1847)
Volutopsius fragilis (Dall, 1891)
V. middendorffii (Dall, 1891)

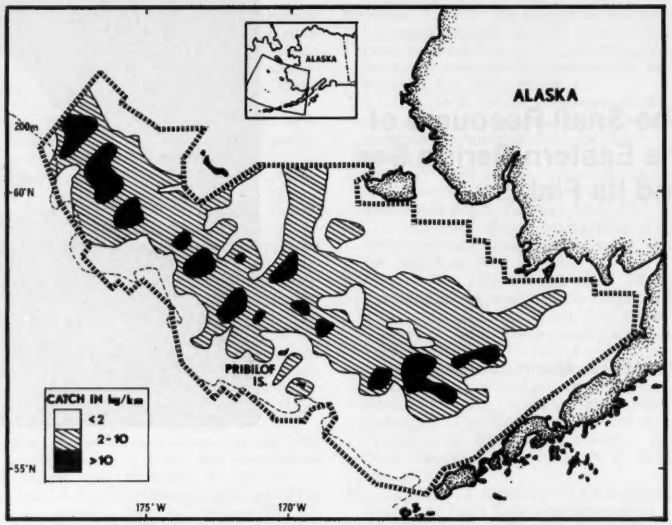

Figure 1.—Location of trawl survey area of the NMFS Northwest and Alaska Fisheries Center in 1975 (inside dashed line) and areas of high snail density (all species combined).

common. The mean shell lengths of *N. pribiloffensis, N. lyrata, N. ventricosa,* and *N. heros* were 100, 115, 102, and 121 mm, respectively (MacIntosh[2]).

The genus *Buccinum* is also well represented in the eastern Bering Sea. Six species of this genus were taken in the 1975 survey, of which four, *B. angulossum, B. plectrum, B. polare,* and *B. scalariforme*, were fairly abundant. Although quite numerous, these smaller snails (58-75 mm average shell length) contribute relatively little to total snail biomass in the eastern Bering Sea. *Buccinum angulossum* (Fig. 3) is representative of the size and general form of these snails.

Most species of eastern Bering Sea snails do not occur over the entire shelf but are retricted to specific depth and temperature regions. In general, those species that have continuous distributions into the Gulf of Alaska inhabit the warmer, deeper waters near the continental shelf edge, while those species having a more northerly distribution into Arctic waters inhabit the colder (at least seasonally), shallower, inshore waters. Basically, *N. pribiloffensis* and *N. lyrata* are temperate water snails and are characteristically found in deeper, warmer waters along the edge of the continental shelf. In contrast, *N. heros* and *N. ventricosa*, which range into the Arctic Ocean, inhabit shallower, seasonally cooler waters near the coast of western Alaska.

Numerous trawl surveys have been conducted in the Gulf of Alaska, but very little attention has been paid to the snail resources of the area. Although quantitative data are lacking, it is apparent that *N. pribiloffensis, N. lyrata,* and *Fusitriton oregonensis* make up the bulk of the snail biomass. *Fusitriton* reaches a length of 13 cm and ranges from the California coast to the Gulf of Alaska and the eastern Bering Sea. All three species occur at depths from at least 50 to 250 m with the latter also found inshore to the intertidal zone. Large catches of *N. pribiloffensis* and *N. lyrata* have been made by trawlers and pot fishermen of Ketchikan, Petersburg, Kodiak, and Cordova. Overall, species diversity appears to be less and distribution of snails appears to be more patchy in the Gulf of Alaska than in the eastern Bering Sea.

Life History

Most snails listed in Table 1 have similar life histories. The sexes are separate and fertilization is internal. Among the large *Neptunea*, sexual maturity occurs at a shell length of 90-110 mm (MacIntosh and Paul, 1977) which probably corresponds to an age of about 10 years. Definitive work on aging has not been completed.

A feature of the life histories of all but one[3] of the common large snails is the production of egg capsules from which crawling young are hatched. Thorson (1950) and Shuto (1974) have discussed this lack of a pelagic larval stage (termed lecithotrophic development) among some Prosobranch gastropods and the effect it has had on their evolution and distribution.

In the eastern Bering Sea, egg clusters are usually laid on the shells of large snails. Both living and dead shells are utilized as substrates, and there appears to be little correlation between the

[2]MacIntosh, R. A. 1976. A guide to the identification of some common eastern Bering Sea snails. Northwest and Alaska Fisheries Center, NMFS, 2725 Montlake Blvd. E., Seattle, WA 98112. Processed rep., 27 p.

[3]*Fusitriton oregonensis*, a member of the tropically oriented family *Cymatiidae*, apparently has pelagic larvae although no literature on the subject exists. Pers. commun. Alan J. Kohn, Univ. Washington, Seattle, WA 98195.

Figure 2.—The four large *Neptunea* from the eastern Bering Sea, clockwise from upper left, *N. heros*, *N. lyrata*, *N. pribiloffensis*, and *N. ventricosa*.

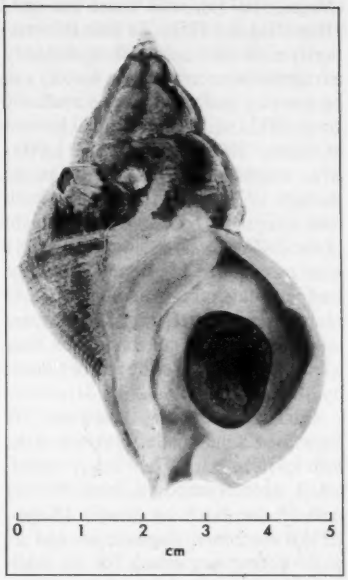

Figure 3.—*Buccinum angulossum*, one of four common *Buccinum* in the eastern Bering Sea.

species of snail depositing its eggs and the species the cases are deposited on. Egg clusters of the large eastern Bering Sea gastropods vary considerably in size, shape, color, and number of individual capsules contained. The capsules, clusters, and young of many species remain undescribed.

Very little is known about the feeding habits of Bering Sea snails. Laboratory studies (Avery[4]) have shown that *Fusitriton oregonesis*, *Neptunea lyrata*, and *Buccinum plectrum* respond to a variety of scents including those of freshly killed mussel, nereid worm, crab, mud shrimp, and fish. Eastern Bering Sea snails are probably facultative predators and scavengers.

Japanese Fishery

Japan has commercially harvested snails in the eastern Bering Sea since at least 1971. The fishery occurs east of long. 175°W on the continental shelf northwest of the Pribilof Islands. Aspects of the commercial fishery have been described, including gear, species captured, and size composition of the catch (Nagai, 1974); incidental catch

[4]Avery, J. 1961. Observation on certain aspects of the feeding habits of four species of carnivorous marine gastropods. Friday Harbor Laboratory Library, Friday Harbor, WA 98250. Unpubl. manuscr., 29 p.

(Nagai, 1975a); and catch-per-unit-effort (Nagai, 1975b). So little information is available for this fishery that only a fragmentary account of its history can be pieced together. Statistics available since 1972 indicated an annual harvest of about 3,000 metric tons (t) (11,000 t live weight) of edible snail meats through 1975 (Table 2). Data for both total weight and recovered meat weight of the 1974 harvest indicated an edible meat recovery of 27 percent. The value compares favorably with values of edible meat recoveries from 26.8 percent to 30.6 percent generated for four species of eastern Bering Sea *Neptunea* by MacIntosh and Paul (1977).

The most common gastropod in Japanese catches made northwest of the Pribilof Islands in 1973 was *N. pribilofensis* which composed about 70 percent of the catch by weight (Nagai, 1974). *Buccinum angulossum* and *B. scalariforme* accounted for an additional 23 percent of the catch.

Until 1977, the number of vessels involved in the fishery was unknown. In some years, the Fisheries Agency of Japan licensed 21 vessels but it is unlikely that all of these vessels actually took part in the fishery. Patrols of NMFS in the eastern Bering Sea observed ony 14, 5, 0, and 6 vessels fishing snails in the years 1971 through 1974, respectively, and no vessels in 1975 and 1976[5]. Records submitted for 1977 by the Japanese in compliance with the Fishery Conservation and Management Act of 1976 indicated that three vessels fished in the eastern Bering Sea (east of long. 175°W) during the year. These vessels were given an allocation of 3,000 t of meat by the North Pacific Fishery Management Council. Fishing began in June and terminated on 16 October, at which time the combined catch of the vessels was 404 t of edible meat—about 15 percent of Japan's allocation. The average catch rate in 1977 was 2.7 t of meats per vessel day.

The 1978 season began in May and ended in November. There was a considerable increase over 1977 in both effort and catch, with about 2,200 t of snail meats taken in about 760-vessel-days (average 2.9 t/day). Fishing effort peaked in August when nine vessels fished northwest of the Pribilof Islands along the edge of the continental shelf. Vessels licensed for this fishery range from 96 to 490 gross t and 25 to 50 m in length (Fig. 4) (unpublished data, U.S. Embassy, Tokyo, Japan). Similar vessels are used in the Japanese longline and crab fisheries in Alaska and, in fact, several vessels fished for crab before switching to the snail fishery in the 1978 season.

Table 2.—Catch and effort statistics of the Japanese snail fishery in the eastern Bering Sea, 1972-78.

Year	Catch (t) edible meat	Total weight[1]	Fishing effort (vessel days)
1972	[2]3,218	11,900	NA[3]
1973	[2]3,319	12,300	NA
1974	[2]3,574	13,237	NA
1975	[2]3,447	12,767	NA
1976	NA	NA	NA
1977	[4]404	1,500	152
1978	[4]2,184	8,100	749

[1]Values are estimates derived from the weight of edible meat and whole snails taken by the fishery in 1974.
[2]Data provided by the Japan Fisheries Agency through the U.S. Embassy, Tokyo, Japan.
[3]Not available.
[4]As reported to the United States under provisions of the Fishery Conservation and Management Act of 1976.

Fishing gear consists of pots fished at intervals on a groundline. The snail pots are truncated cones 88 cm in height (Fig. 5). The diameter of the tunnel in the top of the pot varies from 12 to 15 cm and webbing on the side of the pot is 6-cm mesh over the lower 23 cm of the side and 12-cm mesh on the remainder. Snails, being predators and scavengers, are strongly attracted to the fish bait in the pots.

Little is known about Japanese fishing techniques, but in 1973 one vessel fished about 6,000 pots on 12 groundlines (500 pots/groundline) and took 3 days to pick and re-bait the entire set of gear. An average catch rate of 4 kg/pot per 3-day soak was reported by that same vessel (Nagai, 1975a). In the 1977 fishery, the overall average catch rate was reported as 0.9 kg/pot per 33-hour soak (unpublished data, 1979. Alaska Regional Office, National Marine Fisheries Service, NOAA, Juneau, AK 99802).

All processing of the snail catch now occurs on board the catcher vessel. This consists of crushing the shells, briefly cooking the meats, and removing any soft parts and shell fragments. The meats are graded by size and quality and quick frozen in trays. Small snails in the catch may be frozen whole.

The only available figures on the

Figure 4.—A Japanese snail fishing vessel in the eastern Bering Sea.

[5]The 1974 total included one factoryship which processed snails from the five catcher vessels. This appears to be the only year in which fishing vessels did not process their own catch.

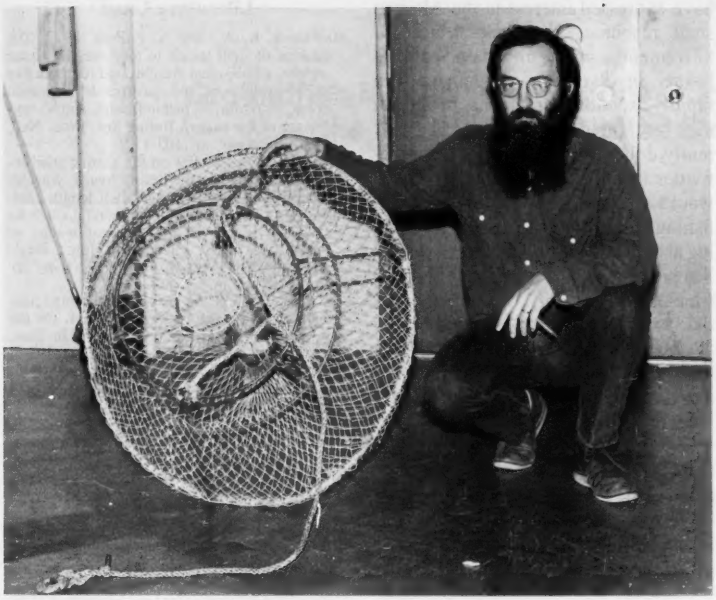

Figure 5.—Snail pot used by the Japanese fishery in the eastern Bering Sea.

value of the snail fishery are derived from estimates of the ex-vessel value of snail meats that are used by the United States as a base for calculating fee schedules for foreign vessels fishing within the extended jurisdiction zone. Fee schedules for the years 1977-79 were based on the ex-vessel snail meat value of $600, $600, and $1,657 per t for the years 1976-78, respectively. The ex-vessel value of snail meats in 1977 was probably higher than the reported $600. At these ex-vessel prices, the 1977 eastern Bering Sea catch was worth only $242,000 and the 1978 catch was worth $1.3 million. In 1979, if the total catch is similar to that made in 1978 (2,187 t of edible meats), its ex-vessel value will probably be in excess of $3.6 million.

Until recently, there was no U.S. regulation of the eastern Bering Sea snail fishery. Implementation of the Fishery Conservation and Management Act of 1976 gave the United States a tool to monitor and manage the snail fishery within the 200-mile conservation zone. At this time, a preliminary management plan developed by NMFS is being used by the North Pacific Fishery Management Council to manage the fishery.

Because there is currently no domestic fishery for snails in the eastern Bering Sea, the total allowable catch has been allocated to Japan, the only nation now involved in the fishery. So little data are available on the snail resource and fishery that Japan's 1977 and 1978 quotas were set at the same level as previous yearly catches, i.e., 3,000 t of edible meats. Changes in total allowable catch and Japan's harvest level will depend upon newly acquired biological and socioeconomic data.

Prospects for a U.S. Snail Fishery

United States fishermen have made little effort to initiate a domestic fishery for snails in the eastern Bering Sea. With only slight modifications, domestic crab vessels currently fishing for king and snow (Tanner) crab in the eastern Bering Sea could fish for snails.

Although there has been little progress toward a domestic snail fishery in the Bering Sea, seafood processors have made several recent attempts to initiate fisheries in other parts of Alaska. In Prince William Sound, as in many other areas of the Gulf of Alaska, snails are regularly taken in crab pots despite the large mesh used. New England Fish Company[6], Petersburg Fisheries, Inc., and others have had samples of Alaskan snails analyzed and have explored marketing possibilities. North Pacific Processors of Cordova, in an effort to build a broader based Prince William Sound pot fishery, installed a snail crushing machine and purchased snails from fishermen during the 1977-78 snow crab season. Only 5,000 pounds of snails were delivered during the season. Small deliveries were attributed to relatively good snow crab fishing, the low price (US$0.06-0.10/pound) paid to fishermen, and the unexpectedly low concentrations of snails encountered.

The current attempt to develop a snail fishery in Nova Scotia, Canada, should be of interest to Alaskan processors. The Nova Scotia Department of Fisheries has developed an escargot-like product that is produced from marine snails similar to those found in Alaska. It is attempting to develop a market for the marine snails *Buccinum undatum* and *Neptunea decemcostata* that are taken in the lobster pot fishery[7].

Discussion

Snails are an underutilized resource in Alaska. Although our knowledge of their distribution and relative abundance is increasing, a data base that provides estimates of stock size and condition is not yet available. Studies on distribution and abundance, species associations, age and growth, trophic

[6]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[7]Ernest Cadegan, Nova Scotia Department of Fisheries, Box 2223, Halifax, Nova Scotia, Canada. Pers. commun.

relationships, and biochemical genetic relationships of four species of eastern Bering Sea *Neptunea* are now being conducted by NMFS.

The prospects for rapid development of Alaska's snail resources are uncertain. Snail stocks in the Gulf of Alaska are essentially unexploited and eastern Bering Sea stocks may well be underexploited. Recent fluctuations in snail catch and effort in the Japanese eastern Bering Sea fishery are probably a response to political and economic factors and not to the availability of snails. The increased cost of distant water fisheries and the remarkably low dockside value of snail meats (est. $1,700/t in 1978) would seem to limit the growth of the fishery. The recent reduction of Japanese snail allocations in the 200-mile fisheries zone of the U.S.S.R. and the strength of the Japanese yen in world money markets, however, might have the opposite effect.

Domestic fishermen and processors have expressed interest in the Alaskan snail resource, but their future involvement is more uncertain than the future involvement of Japan. The rapidly expanding and highly profitable king and snow crab fisheries are currently dominating domestic fishing activities in the area. While crab vessels would be well suited to snail pot fishing, most crab fishermen are looking at Gulf of Alaska and eastern Bering Sea bottomfish stocks as an alternate or supplemental activity. Attempts to initiate a snail fishery in the Gulf of Alaska have not been productive to date. They have been exploratory in nature but show promise as potential off-season operations in the next few years. As in the eastern Bering Sea, the resource and harvesting capacity now exists. Innovative processing and marketing techniques as well as continued increase in the value of the traditional frozen meat product will be necessary conditions for the initiation of a domestic snail fishery.

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Groundfish Monitoring in Sponge-Coral Areas Off the Southeastern United States

H. POWLES and C. A. BARANS

ABSTRACT–Standard trawl survey methods alone are inadequate for assessment of "live-bottom" fish populations off the southeast coast of the United States because of rough bottom and low trawl catches of some commercially important species. Other sampling methods (trapping, underwater television, diver observations) were tested to evaluate their effectiveness for MARMAP surveys in areas characterized by sessile invertebrate communities dominated by sponges and soft corals. A mix of techniques appears to be required to achieve MARMAP objectives of assessment of commercially important species and monitoring of the marine ecosystem: Television photography for location of sponge-soft coral areas prior to sampling, trapping for evaluation of species of low vulnerability to trawls (e.g., red porgy, black sea bass), and trawling with a small mesh liner for sampling of the fish community as a whole, including juveniles.

Introduction

Many groundfish species of the southeastern United States continental shelf are found over large expanses of sandy bottom (Struhsaker, 1969) where their distribution and relative abundance can be routinely monitored by standard otter trawl procedures (Edwards, 1968). These sand bottom species are generally sparsely distributed and of low economic value (Struhsaker, 1969; Barans and Burrell, 1976). Fish species of greater economic value inhabit the sparse and patchily distributed, nearshore sponge-coral ("live bottom") habitats or the offshore rocky outcrop habitats. Fish populations of both habitats are more difficult to inventory because of obstructions to trawling and secretive behavior of the fish.

This report briefly describes the nearshore sponge-coral habitat and evaluates several methods for monitoring relative abundance of groundfish species of these nearshore habitats. The objectives of this study were to: 1) Determine the feasibility of stock inventories with underwater television, including reconnaissance of habitats, fish identifications, and fish enumerations, 2) define the effectiveness of short duration trawl tows with two different nets in sampling the fish community, and 3) identify species effectively sampled by blackfish traps and Antillean "mini-S" traps, and determine the value of trapping in fish stock assessment of selected species.

General Methods

Techniques were tested 7-25 June 1976 in three areas off Charleston, S.C. (Table 1). Diver dependent investigations, including television trials, were limited to Areas 1 and 2, approximately 45 km southeast of Charleston (7-12 June) while trawling and trapping were conducted in Area 3, about 150 km east of Charleston (20-25 June) (Fig. 1).

Following location and mapping of sponge-coral habitat in Area 1, drift transects were made through the area with a diver-held television camera (Table 1). The transects were monitored on deck and recorded on videotape; sections of several transects were also filmed with Super-8[1] color cinema for comparison. Bottom type was checked intermittently between transects throughout this phase. Following transect studies, fish traps (Table 1) were observed approximately every 3 hours for the first 10 hours of a 24-hour soak for analysis of trap performance. Divers recorded individual trap contents with Super-8 cinema film, still color photography, and/or underwater slates. Fish behavior in and about a baited blackfish trap was also observed with a television camera twice

Table 1.—Methods used in three areas off Charleston, S.C., for study of sponge-coral habitat fauna, estimation of fish biomass, and gear evaluation.

Area and Depth	Methods
Area 1 (16-24 m)	Qualitative habitat location and mapping
	SIMRAD echo-sounder survey
	Rock dredge sampling ($N=6$)
	Trawling, 3/4 Yankee #36, 10-minute tows
	Bottom inspection, underwater television ($N=17$)
	Quantitative-fish biomass, gear effectiveness
	Television drift transects ($N=8$)
	Trap fishing characteristics—three blackfish (two baited, one unbaited), three Antillean (two unbaited, one baited)
Area 2 (29-32 m)	Qualitative faunal observations
	Diver observations, photography, 3/4 Yankee # 36 trawl, 10-minute tows ($N=1$)
Area 3 (32-37 m)	Qualitative-habitat location and mapping
	SIMRAD echo-sounder survey
	3/4 Yankee # 36 trawl, 10-minute tows ($N=18$)
	Quantitative-fish biomass, gear comparisons
	3/4 Yankee # 36 trawl, 10-minute tows ($N=12$ day, $N=5$ night)
	URI 60/80 highrise trawl, 10-minute tows 6 day, $N=4$ night)
	Blackfish traps 1-hour sets ($N=6$)
	6-hour sets ($N=24$)
	12-hour sets ($N=9$)
	Antillean traps 1-hour sets ($N=6$)
	6-hour sets ($N=24$)
	12-hour sets ($N=9$)

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MARMAP Contribution No. 162; South Carolina Marine Resources Center Contribution No. 96.
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[1]Mention of trade names or commercial products or firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

during the day and once at night with artificial lighting.

Qualitative observations of habitat type and faunal composition were made in Area 2 (Table 1).

Following delineation of sponge-coral habitat in Area 3, several series of 10-minute trawl tows were conducted in the area with standard Marine Resources Monitoring Assessment and Prediction (MARMAP) trawl (3/4 Yankee #36) and with a high-rise trawl designed for commercial fishing on highly mobile species (the University of Rhode Island, URI, 60/80 highrise). Early tows ($N=6$) with the highrise trawl, not included in the analysis, indicated that at 6.5 kg/hour a wire to depth scope of 5:1 was necessary to keep the 226 kg otter doors from lifting off the bottom. The 3/4 Yankee net was towed with a wire to depth scope of 3:1. Following completion of trawl studies, trapping trials were conducted for 2 days in area 3 (Table 1). Baited and unbaited traps of two types were fished day and night for varying lengths of soaks. Names of fishes reported here, except as noted, follow Bailey et al., (1970).

Surface and bottom water (temperature, salinity, nutrients, and dissolved oxygen) were sampled and expendable bathythermograph casts made at various intervals during the cruise and at 3-hour intervals over a 24-hour period in the area of trapping operations.

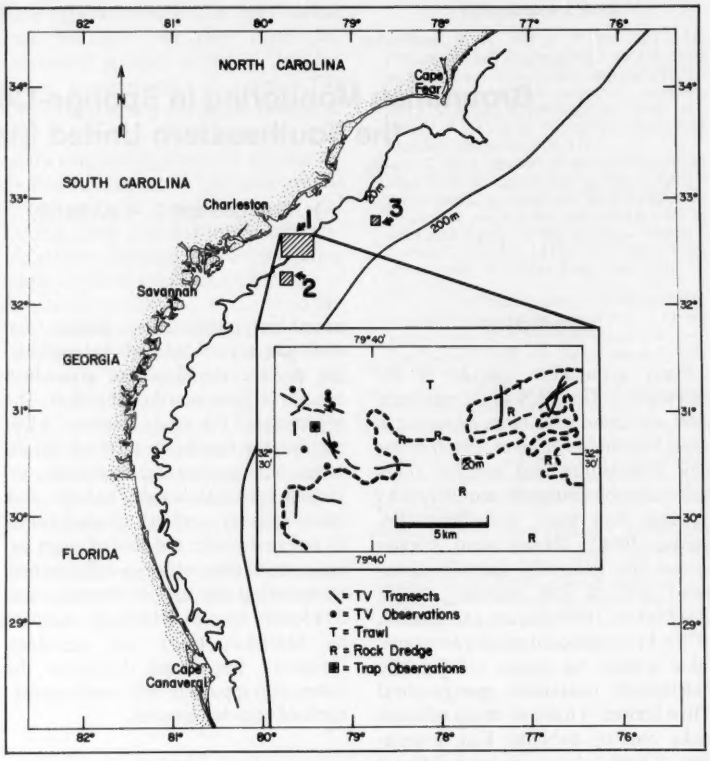

Figure 1.—Areas studied, 7-25 June 1976.

Oceanographic Observations

Observations in Area 1 during 6 days indicated that the water column was relatively homogenous, with only slight differences between surface and bottom temperatures, salinities, and dissolved oxygen (Table 2). Regular fluctuations in current velocity and direction were noticeable near surface and bottom, as inferred from ship's drift and reports from divers. With the underwater television, we often observed soft-bodied attached invertebrates bending under the influence of bottom currents. Drift of the ship progressed through two complete directional cycles each day; velocities ranged from immeasurable to 0.4 m/second during periods of light and variable winds (0-5 kn). Thus, the water column appeared to be under the influence of tidal currents. It is unlikely that transit meanders of the Florida Current affected this area, since the edge of the current was about 19 km further offshore at that time (defined by 23°C isotherm; Kundrat, 1976).

Farther offshore (Area 3, 32-37 m), fluctuations in depth of a strong seasonal thermocline suggested that internal waves of about 12 hours in period passed through the area, while two types of temporary thermoclines reflected local weather conditions. A positive temporary thermocline (temperature increased with depth) at 10-12 m was most pronounced when the temperature of surface waters was below 24.5°C. A negative temporary thermocline (temperature decreased with depth) at 0-6 m occurred when the temperatures of surface waters increased to 25°C or above (Fig. 2). In general, increased barometric pressure was followed by decreased winds and increased air and surface water temperatures. Bottom waters maintained a more constant temperature and salinity than did surface waters (Table 2).

Table 2.—Ranges in oceanographic measurements of the nearshore sponge-coral habitats during June 1976.

Measurements	Area 1 7-12 June Depth 16-24 m 4 observations	Area 3 20-25 June Depth 32-37 m 21 observations
Temperature °C		
Surface	22.87-22.97	24.40-25.30
Bottom	22.85-22.92	23.63-25.57
Salinity ‰		
Surface	34.58-34.61	35.08-35.72
Bottom	34.57-34.58	36.10-36.20
Dissolved O_2 ml/l		
Surface	4.41-4.65	3.92-4.34
Bottom	4.34-4.82	3.66-4.41

Habitat Observations and Description

Divers recorded observations on Formica slates, with a Nikonos II camera (35 mm lens) with strobe flash, and with a Kodak Super-8 camera in an Ikelite housing equipped with Ikelite movie lights. A Hydro Products Model TC-125 television camera (12.5 mm lens) was used, with 61 m of cable connecting it to a Hydro Products 23-cm (9-inch) monitor and control console. A Hydro Products silicon diode light attached to the TV camera and controlled from the shipboard control console was used for some night observations. Recordings were made on 13-mm (½-inch) tape on a Sony Model 3600 videotape recorder. Divers were essentially tethered to the vessel when using the television camera, and swimming with the camera was difficult in any current due to cable drag. Thus TV observations were restricted to near-vessel situations, while slates and film photography were used when greater mobility was required.

The TC-125 camera produced acceptable pictures in all daylight situations encountered, and produced usable pictures without accessory lights until about 10 minutes after sunset on one clear evening. Backscatter from suspended particulate matter impeded visibility when the light was used at night; because of this and unknown effects of lights on behavior of marine organisms, low-light intensifier cameras may provide better fish and habitat observations than light-assisted cameras in limited-light situations.

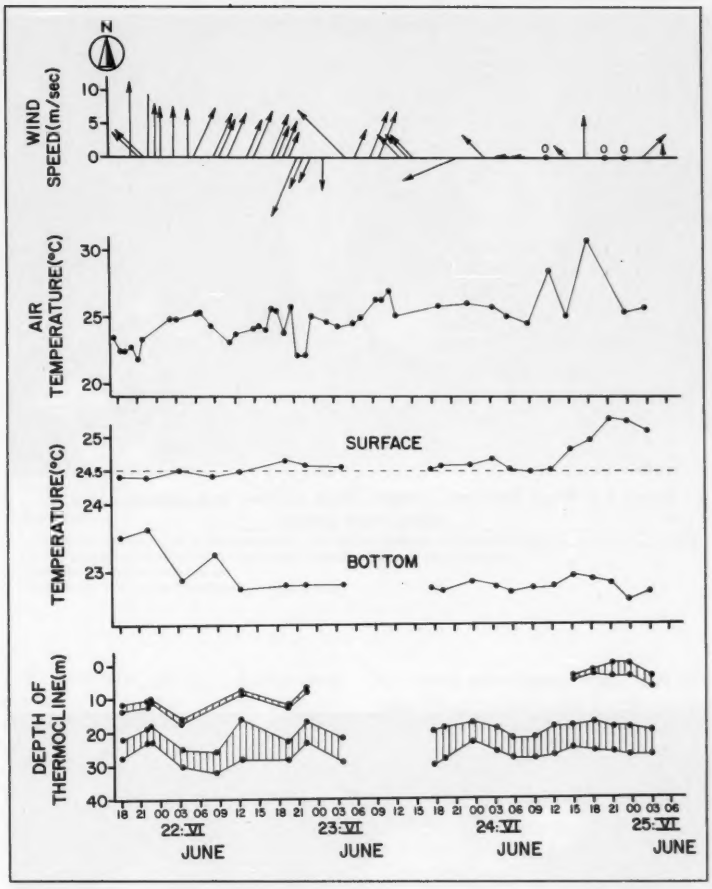

Figure 2.—Oceanographic conditions of sponge-coral habitat, 22-25 June 1976.

Bottom substrate in both Area 1 and Area 2 was generally flat sand, underlain at varying depths by rock. Occasionally the rock layer was exposed, forming flat rocky patches or low ledges up to 30 cm high. Presence of sessile organisms appeared related to presence of rock near or at the surface; at sand layer thicknesses of about 8 cm and less, organisms were attached to the rock. These organisms protruded through the sand cover, often giving the appearance of a "forest" growing from the sand. In areas of sand bottom with no sessile organism cover, no rock was found under the sand to depths of 15 cm. Rock samples from both 18 m and 30 m areas consisted of a tightly cemented limestone conglomerate of carbonate shell and quartz sand material.

Alternating areas of bare sand and organism-covered bottom usually were observed in the areas surveyed by divers and television. Patches of sand (of various sizes to 10 m in diameter) were occasionally found in areas of dense growth, and similar patches of organism growth were found in areas of sand cover. On several occasions, a gradual change from sand with no growth to an area of dense growth occurred over a distance of 10-20 m; transitional areas had interspersed clumps of sand and invertebrate growth.

At one site in Area 1, alternating bands of sand and attached organisms, each band 5 m wide, occurred; surface in the sand bands was approximately 0.5 m lower than surface in the overgrown ridges, so the bottom had a gently undulating appearance. Previous trawl catches of the MARMAP program have suggested that areas of such relatively flat "live bottom" may occur in large patches ≥1 km in extent. Thus patchiness of "live bottom" may occur

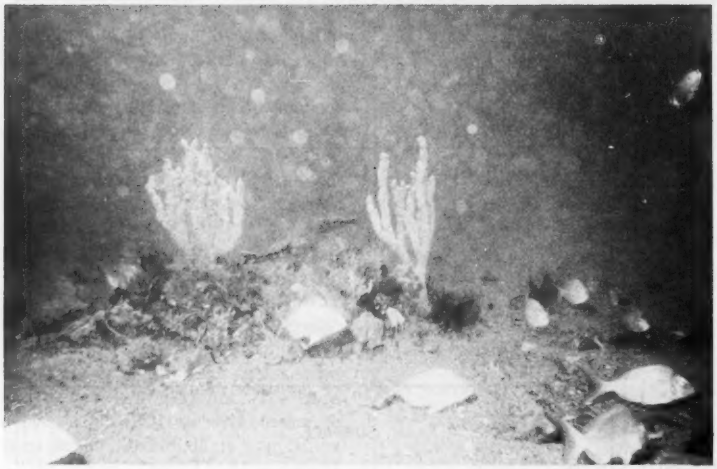

Figure 3.—White branching sponges, black sea bass and southern porgy of sponge-coral habitat.

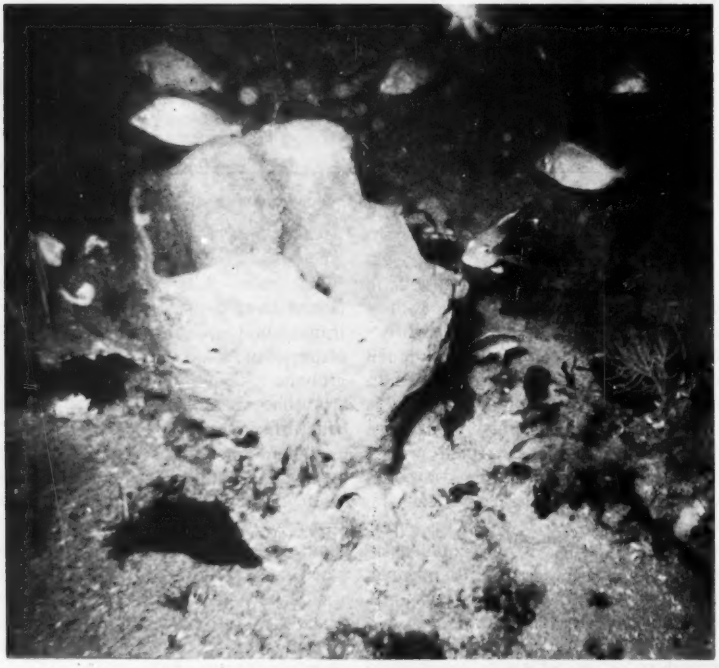

Figure 4.—Barrel sponge of sponge-coral habitat.

on several scales. Large areas, which in the past have been delineated by trawl hauls, may consist of a mosaic of interspersed sand- and organism-covered areas. Although direct observations were not made in Area 3, lack of major trawl damage and large catches of attached invertebrates in this area suggested that Area 3 was also flat with varying densities of attached invertebrates. The complex distribution of sponge-coral habitat on the continental shelf may account for some of the variability in fish abundance estimates made in this study.

Except for the fact that relief was generally low, the topography of our survey areas seems similar to inner-shelf live bottom areas described earlier. Limestone outcrops on the shelf have been known since the late 1800's (Emery and Uchupi, 1972). Off North Carolina, large areas surrounding a rocky reef consist of sand covering depressions in the underlying limestone, producing interspersed sand- and invertebrate-covered limestone areas (Pearse and Williams, 1951). Hunt (1974) found a reflecting seismic layer at 3-6 m below much of the sand surrounding Gray's Reef; this layer was continuous with the outcropping reef limestone rock. If sand layer thickness limits attached invertebrate growth, as appears probable, temporal variability of low relief live bottom areas may be significant, since sediment movement might kill established communities or open new areas for growth.

The sessile organism assemblage in the areas observed was dominated in general appearance by sponges and soft corals, with algae and hard corals occasionally present. Three principal kinds of sponges were observed: White branching sponges (Fig. 3) up to 1 m high, including *Verongia fistularis* and *Axinella polycapella*; low spreading sponges 0.1-0.2 m high and up to 1 m long (species identification not available); and barrel-shaped sponges (Fig. 4) up to 0.6 m high (including *Ircina strobilina* and *Ircinia campana*).

Soft corals were relatively slender and averaged some 0.5 m high; two types have been tentatively identified as *Titanideum* and *Leptogorgia*. Occa-

sional sea fans, *Muricea pendula*, were present. Mound-shaped hard coral colonies, usually 0.3 m high and 0.3 m in base diameter (tentatively, *Solenastrea hyades*) and low, branching hard coral, *Oculina varicosa*, colonies occurred infrequently.

Colonies of bryozoans and ascidians were frequently observed, often associated with the bases of sponges or soft corals. Attached algae formed a minor part of the community. Although sessile invertebrate assemblages of Area 1 and Area 2 appeared generally similar, Area 2 (29-32 m depth) appeared to have a higher proportion of branching sponges and a lower proportion of soft corals than Area 1 (16-24 m). Several large barrel sponges, *Spheciospongia vesparia*, (up to 1.5 m high) were present in Area 2.

Similar types of attached organisms have been collected from or observed in other "live bottom" areas in the South Atlantic Bight. Struhsaker (1969) noted that sponges and sea fans characterized trawl catches from live bottom areas. Sessile invertebrates identified by Pearse and Williams (1951) included 25 species of sponges, as well as hydrozoans, soft corals, and bryozoans, taken from rocky reefs in 4-17 m depth off the Carolinas. Attached algae were abundant in these areas, but appeared to be less common in our survey area. Coral heads, sea fans, algae, and sponges characterize the "coral patches" of Onslow Bay (Huntsman and MacIntyre, 1971); hard corals of the genera *Solenastrea* and *Oculina* occur there as in our survey area. On Gray's Reef off Georgia, the most abundant sessile organisms are soft corals (sea fans and sea whips) and sponges (Hunt, 1974). *Oculina varicosa* is abundant on shelf-edge prominences off eastern Florida (Avent et al., 1977). Hunt (1974) noted that sessile organisms were occasionally attached to rock covered with a thin layer of sand, similar to the situation often observed in our area.

Diver observations and photographs in Areas 1 and 2 showed a fish assemblage numerically dominated by round scad, *Decapterus punctatus*; black sea bass, *Centropristis striata*; and southern porgy, *Stenotomus aculeatus*[2]. All three species were observed on essentially every dive in areas of attached organism growth. Round scad occurred in schools varying from 20 to several hundred fish, and swam slowly 1-2 m off the bottom. They were the only fish commonly observed in areas lacking invertebrate growth. Round scad schools were observed to follow and circle divers. Black sea bass occurred singly, swimming near bottom amongst attached organisms. Southern porgy occurred singly or in groups of several individuals, also near bottom amongst attached organisms. Both black sea bass and southern porgy followed divers, apparently attracted by sediment clouds stirred up; divers collected increasing numbers of such followers as a dive progressed.

Other species observed included small, slow-moving fishes and large roving species (Table 3). Sand perch were fairly common, occurring singly near bottom. Small sea basses, *Serranus* sp., and wrasses, *Halichoeres* sp., were occasionally seen near bottom. Three schools of 6-8 amberjacks, *Seriola* sp., moving rapidly 1-2 m off bottom, and one cobia, *Rachycentron canadum*, were observed. Sheepshead (four individuals together), two lizardfish, and a flounder were also seen in Area 1.

In addition to the species listed (Table 3), a school of several thousand juvenile fish, each some 2.5 cm long, was seen in an area of dense growth in Area 1. These appeared to be juvenile sand perch. This suggests that sand perch may aggregate during the juvenile stage, in contrast to adults which, from diving observations and trawl survey data, appear to be dispersed.

None of the fishes observed showed noticeable reactions to the divers within their field of view (average visibility was some 7.5 m). It is possible, however, that some species or life history stages of species observed may have avoided or been attracted to the divers outside their field of visibility. More kinds of fish were observed at Area 2 (29-32 m) than at Area 1 (16-24 m), despite the shorter time spent making

Table 3.—Fish species sampled by traps and observed on videotapes and by divers.

Species	Blackfish traps (39 sets) Wt (kg)	Blackfish traps (39 sets) No.	Antillean traps (39 sets) Wt (kg)	Antillean traps (39 sets) No.	Television (4.14 km)	Divers (50 dives)
Black sea bass	95.2	287	39.7	121	205	A[1]
Red porgy	52.4	160	58.2	146	—	—
Tomtate	4.5	26	6.9	46	11	R
Bank sea bass	4.8	24	4.8	25	—	R
Southern porgy	1.2	11	2.6	22	294	A
Vermilion snapper	0.6	3	3.9	15	—	R
Gray triggerfish	1.4	3	12.6	9	—	—
Moray eel	0.7	3	—	—	—	R
Toad fish[2]	0.4	1	—	—	—	—
Banded rudderfish	—	—	219.3	87	15	O
Planehead filefish	—	—	1.8	14	—	—
Sand perch	—	—	1.3	6	—	C
Bermuda angelfish[2]	—	—	0.1	2	—	R
Cubbyu[2]	—	—	0.1	1	—	—
Conger eel[2]	—	—	2.6	1	—	—
Round scad	—	—	—	—	A[3]	A
Seabasses (*Serranus* spp.)	—	—	—	—	3	O
Wrasses (*Halichoeres* spp.)	—	—	—	—	3	C
Sheepshead	—	—	—	—	5	R
Lizard fish (*Synodus* sp.)	—	—	—	—	1	R
Flounder (Bothidae)	—	—	—	—	—	R
Cobia	—	—	—	—	1	R
Cardinalfishes (*Apogon* spp.)	—	—	—	—	—	O
Blennies (Clinidae)	—	—	—	—	—	O
Combtooth blennies (Blenniidae)	—	—	—	—	—	O
Reef butterflyfish	—	—	—	—	—	R

[1]A= Abundant (numerous on all transects/dives); C= Common (present on most transects/dives); O= Occasional (present on few transects/dives); and R= Rare (total 1-2 specimens on all transects/dives).
[2]Species caught only during one set.
[3]Could not be enumerated from television observations.

[2]Taxonomic revision by R. H. Dawson (1979).

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observations, and several fishes characteristic of warm water (cardinalfishes, blue angelfish, and reef butterflyfish) were seen at the deeper site (Table 3). Several goby-like fish (tentatively, *Ioglossus calliurus*) about 8 cm long were seen hovering about 0.5 m off bottom. These fish dove into the substrate at the approach of a diver.

The lack of fish sightings on sand bottom areas and the relatively high numbers seen over areas of invertebrate growth correspond well with our own earlier trawling observations during 6 years of MARMAP trawling studies in the South Atlantic Bight and with Struhsaker (1969) that fish abundance and diversity are substantially greater in sponge-soft coral habitat areas than in sand bottom areas. Most of the species observed by us were listed by Struhsaker (1969) as "live-bottom" species, including the large, roving amberjacks and cobia which might have been expected to occur independently of bottom cover. Several "tropical" species seen in Area 2 in the present study are also found in "coral patches" in Onslow Bay (Huntsman and MacIntyre, 1971), although a greater diversity of such fishes is present in Onslow Bay than was seen during the limited observation time of our survey.

Television Transect Studies

Bottom type and proportion of substrate covered by sessile organisms were observed and fish counts were made by letting the ship drift with the television camera down. A first series of observations was made with the camera, weighted with a 45-kg weight, suspended 2 m off bottom and pointing vertically downward (Fig. 5a). A second series of transects was made with divers holding the camera near horizontal 1.5 m off bottom and slowly panning it 45° on either side of their line of progress (Fig. 5b). Drift speed due to wind and current in both series was approximately 0.25-0.5 m/second.

Habitat type and sessile organism density could be assessed with the vertically directed camera, but this technique was not suitable for making fish counts. Proportion of bottom covered by sessile organisms could be estimated, and slow-moving mobile invertebrates (e.g., crab, sea stars) were observed. However, we found it impossible to identify attached organisms even to major taxonomic groups. No fishes were observed except for several small black sea bass following the camera and weight along the bottom; probably other fish avoided the limited field of view.

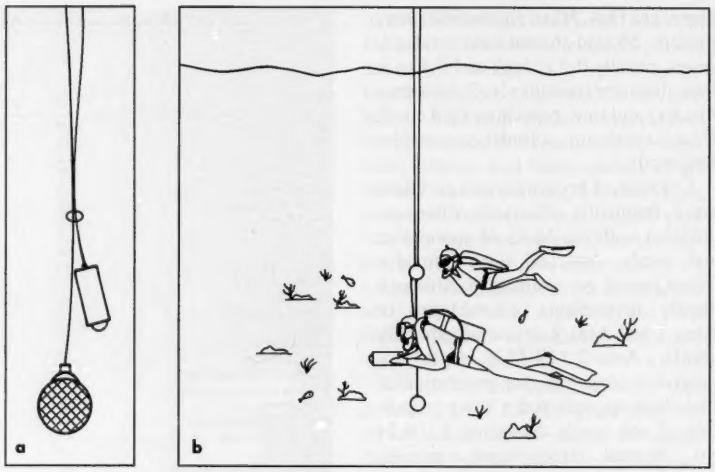

Figure 5a.—Underwater television camera in vertical position above 45.4 kg ball. Figure 5b.—Underwater television camera being panned along horizontal transect by divers.

This technique was usable in swells or waves up to 1.5 m high and winds up to 12 m/second. In rougher conditions camera movement due to ship's roll and risk of equipment damage precluded making observations. Since vertically directed television is simple to operate and usable in moderately rough weather conditions, this technique will be suitable for rapid identification of sponge-coral habitat in future studies.

Horizontal scanning of the camera produced pictures of sessile organisms suitable for identification to major taxonomic groups, and permitted identifying and counting fishes. As with the vertically directed camera, proportion of bottom cover could be estimated. Identification of more abundant fishes to species was possible; for very small, rare, or morphologically similar species, identifications to the genus level were made. This technique was more weather-restricted than the vertically-directed unmanned camera, since divers were not used in winds over 5 m/second. Depth limitations for research diving, as well as weather, would preclude using this technique for routine fish assessment throughout the South Atlantic Bight; however, use of a towed vehicle to orient the camera horizontally would permit similar photography under conditions unsuitable for research diving.

Eight television transects made with the panned camera were videotaped, and fish counts were made from the tapes ashore, using a 48-cm (19-inch) monitor (Table 4). This method is similar to the swimming transect method of Brock (1954) and the cinetransects of Alevizon and Brooks (1975). Data from three transects (275, 276, 280) were pooled since these were short and made close together.

Three teams of three people each identified and counted fishes from the tapes. Individual black sea bass and southern porgy, being relatively slow-moving, could generally be identified using bottom features; thus multiple counting of individuals was minimized. Individual species counts varied somewhat between teams. The two counts for each transect which

Table 4.—Estimated numbers and biomasses of southern porgy and black sea bass on television transects.

Item	Transect					
	275,276, 280	281	282	283	309	313
Transect Data						
Length (m) (Loran-A)	1,070	440	930	630	410	660
Area (m^2)	10,700	4,400	9,300	6,300	4,100	6,600
Length (m) (Diver-estimated)	3,000	611	704	648	611	611
Southern porgy						
Number of fish	102	50	47	7	40	48
(Average of counts in parenthesis)	(93,110)	(62,34)	(36,58)	(8,6)	(40,39)	(43,52)
Number/ha	95	114	51	11	98	73
Biomass (kg/ha)	9.5	11.4	5.1	1.1	9.8	7.3
Black sea bass						
Number of fish	66	29	31	[1]27	14	38
(Average of counts in parenthesis)	(55,78)	(28,30)	(29,33)		(15,14)	(33,44)
Number/ha	62	66	33	43	34	58
Biomass (kg/ha)	9.3	9.9	5.0	6.4	5.1	8.7

[1]Only one count available.

agreed most closely were averaged to give an estimate of number of fish present on the transect. Agreement was best on rare species, poorest on the most abundant species (scads and southern porgy).

Numbers and biomass per unit area of southern porgy and black sea bass were estimated from television transect data (Table 4). Accurate counts of round scad, the most abundant species numerically, were impossible due to their great abundance and to their circling of divers. Other species occurred so rarely that biomass estimates would have little meaning. Width of the TV transect was estimated at 10 m, from visibility measurements (average approximately 7.5 m) and panning angle (45° each side of the line of progress). Transect length was estimated by start and finish LORAN-A bearings. Transect lengths from LORAN-A bearings were checked using average drift speed as estimated by the divers (0.25-0.50 m/second) and lengths of time spent on the transects (Table 4). Agreement was good on two transects, fair on three, and relatively poor on one (transects 275, 276, 280 combined). Both methods of transect length estimations are quite imprecise and this would represent the major source of error in our biomass estimates. Although LORAN bearings taken during drift transects suggested that drift may have been zigzag, drifts did not appear to cover any area more than once. Individual fish weights (100 g for southern porgy, 150 g for black sea bass) were estimated from the mean weight of specimens from trawl and trap hauls in the same area. Estimated densities ranged from 11 to 114 fish/ha for southern porgy and from 33 to 66 fish/ha for black sea bass, while estimated biomass ranged from 1.1 to 9.8 kg/ha for southern porgy and from 5.1 to 9.9 kg/ha for black sea bass (Table 4). Thus density and biomass for southern porgy were more variable (varying by a factor of 10) than for black sea bass (varying by a factor of 2). Total biomass for these two species combined ranged from 7.5 to 21.3 kg/ha.

Preliminary number and biomass estimates made in this survey were subject to several sources of error, but we believe that these can be minimized and that television transects justify further study as a means of estimating demersal fish populations in sponge-soft coral areas. The fact that black sea bass and southern porgy followed divers did not appear to affect counts, since these accumulations of fishes remained behind the divers and thus out of the field of view of the camera. Neither attraction to nor avoidance of divers was observed in front of the camera, although it is possible that these fish responses may have occurred outside the field of visibility. Identification of fish from videotapes may prove difficult in an area of high species diversity. This problem might be solved by using divers, or remotely operated color still photography in depths beyond diving capability, for "ground-truth" identification. Transect length measurements, based on LORAN-A, were probably the major source of error. Accuracy could be increased by using radar ranges from a buoy dropped at the beginning of a transect. Transect width measurements could be made more precise by measuring visibility at the beginning and end of each transect rather than using an average for all transects as was done in the present study. Mean fish size in a given area could be more accurately estimated from more complete catch sampling within the area of the TV observations.

Total biomass estimates of the two predominant demersal fish species calculated from our observations (7.5-21.3 kg/ha) are low compared with fish biomass estimates from other marine habitats (summarized by Russell, 1977). Values of less than 50 kg/ha have been found in soft-bottom demersal fishing areas off New England and in the English Channel, on sand bottoms off Texas, and in sand or low-relief shallow reef areas off New Zealand and near coral reefs. Biomass estimates for high-relief rocky reefs off New Zealand, kelp beds off California, and coral reefs are characteristically from 10 to 100 times greater than our estimates. Russell (1977) found that fish standing crop was higher on topographically complex sites than on flat-bottom sites on New Zealand rocky reefs, so that the flat nature of the habitat we surveyed may account for the apparently low standing crops observed.

Trawl Catch Comparisons

Short duration (10 minutes) bottom trawl tows were used in an attempt to reduce the damage to gear and loss of valuable information that is normally encountered during standard (30 minutes) trawling over areas of bottom relief and/or attached benthic organisms. The 3/4 version of a Yankee 36 trawl net with 1.3-cm cod-end liner (Wilk and Silverman, 1976) has been used for

Table 5.—Numbers of fish caught (mean/variance) in trawl and trap collections 20-25 June 1976, Area 3.

	Baited trap sets (6 hours)				Trawl tows (10 minutes)			
	Blackfish		Antillean Mini-S		3/4 Yankee 36		URI Highrise	
Item	Day (12)	Night (12)	Day (4)	Night (4)	Day (12)	Night (5)	Day (6)	Night (4)
Numbers								
Tomtate	$^{1}0^{+}/0^{+}$	1/1	2/7	4/15	28/1,261	41/153	22/743	47/278
Southern porgy	$0^{+}/0^{+}$	0/0	2/5	0/0	17/314	8/78	9/199	101/3,266
Black sea bass	8/64	9/44	8/83	8/6	$0^{+}/0^{+}$	1/0	$0^{+}/1$	5/16
Red porgy	10/85	1/1	16/26	6/16	$0^{+}/0^{+}$	$0^{+}/0^{+}$	29/4.296	2/2
Total	19/56	12/43	35/226	21/18	105/7,747	149/1,744	75/4,002	226/4,760
Weights (kg)								
Tomtate	1/1	$0^{+}/0^{+}$	$0^{+}/0^{+}$	$1/0^{+}$	2/4	5/2	3/12	6/8
Southern porgy	$0^{+}/0^{+}$	0/0	$0^{+}/0^{+}$	0/0	1/2	1/1	$0^{+}/1$	9/32
Black sea bass	2/5	3/6	2/6	3/2	$0^{+}/0^{+}$	$0^{+}/0^{+}$	$0^{+}/0^{+}$	2/2
Red porgy	3/9	$0^{+}/0^{+}$	6/10	3/4	$0^{+}/0^{+}$	$0^{+}/0$	15/1,152	$1/0^{+}$
Total	6/7	4/6	12/81	8/5	12/77	18/24	38/2,665	32/80

$^{1}0^{+}$ = value $>0<<1$.

monitoring fish populations in the South Atlantic Bight for over 8 years. The URI 60/80 highrise net without cod-end liner (Hillier, 1974) has been used by commercial fishermen in the area since 1976 (Ulrich et al., 1976). Both nets were believed to sample different segments of the sponge-coral groundfish community.

The number of replicate trawl tows completed under each set of conditions (Table 5) reflected greater available time during daylight periods and greater difficulty/time needed for handling the URI net. Collections made near (± 1 hour) sunrise or sunset were excluded from analysis because of their small number.

The numbers (Table 5) and weights of fish caught by the trawls were highly variable with a negative binomial frequency distribution ($S^2 >> \bar{x}$), therefore a log $(x+1)$ transformation was made to the data prior to comparison of results with a one-way analysis of variance. Mean numbers of fish (all species) and numbers of selected priority species were chosen for primary statistical analysis for ease of comparison with counts of fish from TV transects.

Few statistically significant differences between catches by trawl type (day and night) or between catches day and night by the same trawl type could be demonstrated due to the high variance.

Although the 3/4 Yankee trawl caught a greater diversity of species (Table 6), it caught significantly fewer fish ($P=0.05$) than the URI highrise trawl during night. Differences between mean number of fish caught by the two gear types during the day were insignificant. The URI highrise trawl caught significantly more fish at night than during the day, while the 3/4 Yankee did not.

The 3/4 Yankee trawl, probably because of its small-mesh liner, caught smaller species of fishes than the URI net. The five most abundant small species caught by the 3/4 Yankee but not by the URI net were tattler, *Serranus phoebe*; seaweed blenny, *Blennius marmoreus*; offshore lizardfish, *Synodus poeyi*; checkered blenny, *Starksia ocellata*; and pearly razorfish, *Hemipteronotus novacula* (Table 6). Many of the less abundant species taken by the 3/4 Yankee trawl but not by the URI trawl (Table 6) are also small as adults. Juveniles of commercially important species and prey organisms are small, and a groundfish community assessment program should sample both of these community components.

Groundfish species of particular interest in our trawl comparisons include black sea bass and southern porgy, which were identified as abundant in sponge-coral areas by divers and underwater TV, and red porgy which have commercial value and tomtate which were relatively abundant in trawl catches.

Southern porgy was the most abundant species in URI highrise catches and fourth most abundant in 3/4 Yankee catches (Table 6). Mean catch was greatest (101 per tow) at night with a URI net (Table 5). This mean catch of southern porgy at night was significantly different from the mean URI day catch ($P=0.01$) and significantly greater than mean night catch with the 3/4 Yankee trawl ($P=0.01$).

Black sea bass catches by both trawl types were low (Table 5) and differences between the catches of the 3/4 Yankee and URI highrise for the same time period were not significant. Mean catch (numbers) of black sea bass at night was significantly greater than day catch for both gear types ($P=0.05$).

A single large catch of red porgy (165 fish) in the URI trawl greatly increased the catch variability; generally both trawls caught low numbers of red porgy (Table 5). No more than a single red porgy was caught in any 3/4 Yankee tow. The URI trawl caught significantly more fish than the 3/4 Yankee during the night but not during the day. No significant differences existed between day and night catches of red porgy within gear types.

Tomtate were the most abundant species in 3/4 Yankee catches and were third in abundance in URI catches (Table 5). Between-trawl catch differences were insignificant for a given period, and day-night differences were insignificant for a given gear.

Fish abundance and biomass estimates of particular species or the total fish community based on bottom trawl catches in Area 3 must be regarded as minimum estimates due to the selectivity of the gear. Both abundance and biomass estimates were calculated by expansion of the number or weight of fish caught on the average area covered by the trawl, assuming: 1) The density

Table 6.—Mean number of fish caught by trawls and traps in Area 3.

Rank	Common and Scientific Names[1]	3/4 Yankee trawls (18) Mean catch/tow	URI trawls (13) Mean catch/tow	Antillean traps (8) Mean catch/6 h	Blackfish traps (24) Mean catch/6 h
1	Tomtate[2], *Haemulon aurolineatum*	33.72	25.08	3.0	0.875
2	Planehead filefish, *Monacanthus hispidus*	15.56	28.15	1.125	
3	Vermilion snapper[2], *Rhomboplites aurorubens*	15.17	1.92	0.375	0.0833
4	Southern porgy, *Stenotomus aculeatus*	13.67	35.46	1.00	0.0833
5	Blue angelfish, *Holacanthus bermudensis*	7.94	3.38	0	
6	Twospot cardinalfish, *Apogon pseudomaculatus*	7.89			
7	Whitebone porgy[2], *Calamus leucosteus*	5.00	2.38		
8	Bank sea bass, *Centropristis ocyurus*	2.22	0.15	1.25	0.5417
9	Cubbyu, *Equetus umbrosus*	2.06	0.69	0.125	
10	Barbfish, *Scorpaena brasiliensis*	1.78	0.54		
11	Tattler, *Serranus phoebe*	1.72			
12	Spotfin butterflyfish, *Chaetodon ocellatus*	1.67	1.62		
13	Knobbed porgy, *Calamus nodosus*	1.22	0.23		
14	Reef butterflyfish, *Chaetodon sedentarius*	1.17	0.38		
15	Round scad, *Decapterus punctatus*	1.11			
16	Seaweed blenny, *Blennius marmoreus*	0.94			
17	Deepwater squirrelfish, *Holocentrus bullisi*	0.94			
18	Sand perch, *Diplectrum formosum*	0.83	0.08	0.50	
19	Bigeye, *Priacanthus arenatus*	0.56	0.54		
20	Short bigeye, *Pristigenys alta*	0.56			
21	Offshore lizardfish, *Synodus poeyi*	0.39			
22	Black sea bass[2], *Centropristis striata*	0.33	1.62	8.375	8.458
23	Yellowtail reeffish, *Chromis enchrysurus*	0.33	0.15		
24	Jackknife-fish, *Equetus lanceolatus*	0.33	0.85		
25	Scrawled cowfish, *Lactophrys quadricornis*	0.33	0.15		
26	Dotterel filefish, *Aluterus heudeloti*	0.28	0.38		
27	Checkered blenny, *Starksia ocellata*	0.28			
28	Red porgy[2], *Pagrus sedecim*	0.22	14.54	11.125	5.667
29	Bandtail puffer, *Sphoeroides spengleri*	0.22			
30	Shrimp flounder, *Gastropsetta frentalis*	0.17	0.08		
31	White grunt[2], *Haemulon plumieri*	0.17	0.31		
32	Pearly razorfish, *Hemipteronotus novacula*	0.17			
33	Dusky flounder,*Syacium papillosum*	0.17	0.38		
34	Sand diver, *Synodus intermedius*	0.17			
35	Spotted burrfish, *Chilomycterus atinga*	0.11			
36	Conger eel, *Conger oceanicus*	0.11		0.125	
37	Clearnose skate, *Raja eglanteria*	0.11			
38	Lantern bass, *Serranus baldwini*	0.11			
39	Inshore lizardfish, *Synodus foetens*	0.11			
40	Snakefish, *Trachinocephalus myops*	0.11			
41	Orange filefish, *Aluterus schoepfi*	0.06			
42	Bridle cardinalfish, *Apogon aurolineatus*	0.06			
43	Bronze cardinalfish, *Astrapogon alutus*	0.06			
44	Eyed flounder, *Bothus ocellatus*	0.06	0.38		
45	Spotfin flounder, *Cyclopsetta fimbriata*	0.06			
46	Skiletfish, *Gobiesox strumosus*	0.06			
47	Slippery dick, *Halichoeres bivittatus*	0.06			
48	Fringed filefish, *Monacanthus ciliatus*	0.06			
49	Reticulate moray, *Muraena retifera*	0.06			
50	Blackbar soldierfish, *Myripristis jacobus*	0.06			
51	Lesser electric ray, *Narcine brasiliensis*	0.06			
52	Emerald parrotfish, *Nicholsina usta*	0.06			
53	Roughback batfish, *Ogcocephalus parvus*	0.06			
54	Polka-dot batfish, *Ogcocephalus radiatus*	0.06			
55	Bank cusk-eel, *Ophidion holbrooki*	0.06			
56	Oyster toadfish, *Opsanus tau*	0.06			
57	Polka-dot cusk-eel, *Otophidium omostigmum*	0.06			0
58	Summer flounder, *Paralichthys dentatus*	0.06	0.08		
59	French angelfish, *Pomacanthus paru*	0.06	0.08		
60	Bandtail searobin, *Prionotus ophryas*	0.06	0.15		
61	Greater soapfish, *Rypticus saponaceus*	0.06			
62	Smoothhead scorpionfish, *Scorpaena calcarata*	0.06			
63	Bluehead, *Thalassoma bifasciatum*	0.06			
64	Scrawled filefish, *Aluterus scriptus*		0.08		
65	Southern stargazer, *Astroscopus y-graecum*		0.08		
66	Gray triggerfish, *Balistes capriscus*		0.08	0.875	.04167
67	None *Bothus robinsi*		0.08		
68	Flying gurnard, *Dactylopterus volitans*		0.08		
69	Roughtail stingray, *Dasyatis centroura*		0.08		
70	Spottail pinfish, *Diplodus holbrooki*		0.23		
71	Naked sole, *Gymnachirus melas*		0.08		
72	Lancer stargazer, *Kathetostoma albigutta*		0.15		
73	Hogfish[2], *Lachnolaimus maximus*		0.08		
74	Yellowmouth grouper[2], *Mycteroperca interstitialis*		0.08		
75	Gag[2], *Mycteroperca microlepis*		0.08		
76	Scamp[2], *Mycteroperca phenax*		0.08		
77	Atlantic midshipman, *Porichthys porosissimus*		0.08		
78	Bluespotted searobin, *Prionotus roseus*		0.08		
79	*Gymnothorax saxicola*		0.00		0.04167
80	Banded rudderfish, *Seriola zonata*		0.00	10.875	
	Total number of species	63	42	13	9

[1]Names of fishes follow Bailey et al. (1970) except for southern porgy (text footnote 2).
[2]Species of commercial interest.

Table 7.—Groundfish abundance and biomass estimates in Area 3 from largest mean trawl catch values.

Species	Largest value	Abundance (No./ha)	Biomass (kg/ha)
Tomtate	3/4 Yankee/night	44	5.1
Southern porgy	URI/night	72	6.5
Black sea bass	URI/night	3	1.1
Red porgy	URI/day	21	10.6
Total (all species combined)	URI/night	190	27.3

of fish was similar throughout the habitat, 2) the distance covered by each trawl, at 6.5 km/hour, was 1.08 km per 10 minutes, 3) the 3/4 Yankee net spread was 0.0087 km (Azarovitz[3]), and 4) the URI highrise net spread was 0.0129 km (the same proportion to total footrope length as the 3/4 Yankee). To reduce the variability in both abundance and biomass estimates, we have asumed that all values for a given time period or gear type less than the maximum value were the result of fish avoidance or gear selectivity, and did not adequately reflect the abundance or biomass of the area. Therefore, the largest mean value (3/4 Yankee/URI highrise and day/night) were selected as maximal estimates of the fish populations (Table 7). The total groundfish abundance estimate (all species) for Area 3 was 190 fish/ha, while the total biomass estimate was 27.3 kg/ha. Southern porgy were most abundant (72 fish/ha). Red porgy were greatest in biomass (10.6 kg/ha) due to their large mean size, although they were low in trawl-based estimates of abundance (21 fish/ha).

In general, television estimates of southern porgy and black sea bass density and biomass were greater than trawl estimates (Table 8). In a specific comparison, 10-minute trawl hauls were made adjacent to two television transects. Biomass estimates for TV density values were expanded from mean weights of fish caught by hook and line in the area, and trawl estimates were made as above. In this comparison, the trawl density estimates were lower than TV estimates except for

[3]T. Azarovitz, Northeast Fisheries Center, NMFS, NOAA, Woods Hole, MA 02542. Pers. commun.

Table 8.—Fish density and biomass estimates from television transects and trawl hauls. Comparisons of adjacent samples and general ranges in mean estimates.

Item	Area 1 TV 309	Area 1 Trawl 106	Area 1 TV 313	Area 1 Trawl 107	Area 1 (TV, range of 6)	Area 3 (3/4 Yankee, range of means for 12 day 5 night)	Area 3 (URI, range of means for 6 day 4 night)
Southern porgy							
number/ha	98	6	73	694	11-114	8-18	6-72
kg/ha	9.8	0.4	7.3	39.1	1.1-11.4	0.7-1.3	0.4-6.5
Black sea bass							
number/ha	34	0	58	31	33-66	<1-1	<1-3
kg/ha	5.1	0.0	8.7	3.2	5.0-9.9	0.1-0.2	<0.1-1.1

Table 9.—Times (EDT) that traps were observed to define fish attraction and escapement responses.

Trap	Time set	Observation times/type[1], 9 June				Time hauled, 10 June
Baited blackfish #1	0815	0932/8mm	1115/DC		1742/8mm	0655
Baited blackfish #2	0820	1005/8mm	1133/DC		1717/8mm	0650
Unbaited blackfish	0752	1053/DC	1256/8mm	1555/35mm	1825/DC	0703
Baited Antillean	0810	0932/8mm	1155/DC		1730/8mm	0650
Unbaited Antillean	0759	0849/TV	1044/DC	1239/8mm	1837/DC	0700
Unbaited Antillean	0805	1106/DC	1316/DC	1545-35mm	1816/DC	0705

[1]The types of observations include: DC = diver's count; 8mm = 8mm film; 35mm = 35mm film; and TV = television videotape.

southern porgy on one occasion (Table 8). In comparisons of TV estimates in Area 1 and trawl estimates in Area 3, TV estimates were again greater, particularly for black sea bass where the difference was by a factor of 10 (Table 8). The direct trawl-TV differences may have been due to small-scale habitat patchiness; trawl and television estimates were made close together but not on identical areas. However, particularly for black sea bass, it appears that TV provides higher density and biomass estimates than the trawl. Further comparative sampling, with number of samples adequate for statistical comparison or direct attachment of TV onto the trawl to enable sampling the same area at the same time, would be required for more precise comparison of trawl and television standing crop estimates.

The 3/4 Yankee net with a cod-end liner caught a greater number of species, and fish of smaller sizes, than the URI highrise, and should be an acceptable gear to routinely monitor the groundfish community, including juveniles and prey species. Although the URI net caught more adults of commercial species than the 3/4 Yankee, catches were not large enough to justify selecting it as a survey gear over the 3/4 Yankee. There were no significant differences between trawls in day catches of four major fish species, but the URI trawl at night caught significantly more red porgy and southern porgy than did the 3/4 Yankee trawl.

Values of total fish abundance estimated for both gears were similar during daytime, but varied by a factor of 2 at night. Since the URI trawl was catching primarily larger specimens and the 3/4 Yankee was catching primarily small individuals, each net was missing a significant part of the groundfish community by daytime avoidance and gear selectivity. The ideal situation might be to routinely have underwater TV camera and trawl operate simultaneously to evaluate the habitat types throughout each trawl tow and estimate a vulnerability factor for each species during each tow.

Trap Catch Comparisons

Trapping has been evaluated extensively in the Caribbean to define optimum fishing conditions (Wolf and Chislett, 1974), but not as a method of assessing abundance of fish within populations. Although a winter commercial trap fishery for black sea bass exists in shallow waters of the continental shelf off the Carolinas (Rivers, 1966), no information is available on trapping as a method of measuring the relative abundance of fish species in this area. This study describes groundfish attraction and escapement responses from observations of fish behavior near and in traps and identifies optimum catch conditions (trap type, period of soak, time of day, and presence or absence of bait) in an attempt to establish a standard sampling procedure for determining the relative abundance of several fish species.

Two trap types were used throughout. The first was a "blackfish trap" (Rivers, 1966), with dimensions of $60\times60\times52$ cm and volume about 0.19 m^3. Each had four lower external funnels into a lower compartment and two internal funnels into the upper trap. The second, an Antillean S-trap, was our modification of a trap commonly used off Cuba (Munro et al., 1971), with dimensions of $65\times125\times110$ cm and volume about 0.89 m^3. This trap had two large funnels on opposite sides of the trap. Both types of traps were constructed of galvanized wire netting with hexagonal mesh ($5\times4\times4.5$ cm).

Observations of fish behavior in and near the two types of traps were conducted on 9 June 1976 in Area 1. Three baited and three unbaited traps were positioned around the anchored ship at distances $\geq$100 m from each other. Traps were set between 0752 and 0820 hours EDT and observed approximately every 3 hours throughout the remaining daylight hours (Table 9). Number of fish within each trap and fish behavior were recorded on slates and by Super-8 cinema and 35 mm still photography (Fig. 6). During the 22 hours, 30 minutes to 23 hours, 11 minutes soak times, the area was exposed to almost two complete tidal cycles with associated cycles of current direction and velocity. Traps were retrieved between 0646 and 0705 hours EDT on 10 June 1976.

Black sea bass and southern porgy, which were most abundant in trap catches during the fish behavior experiment, were also the two demersal species most commonly observed by divers in Area 1. Other species occasionally caught included bandtail puff-

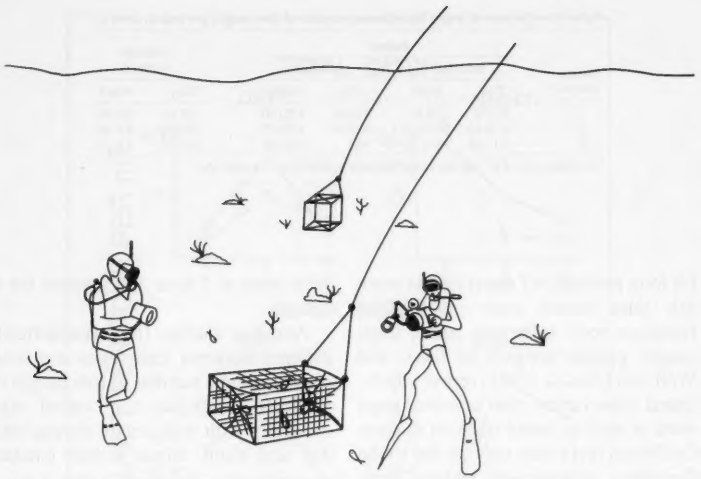

Figure 6.—Divers recording fish behavior and trap catches.

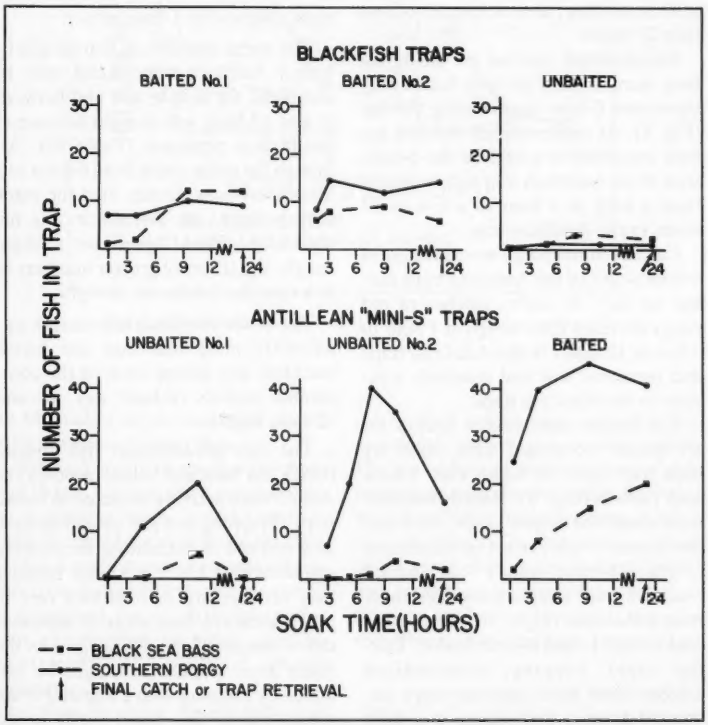

Figure 7.—Temporal change in numbers of fish in each trap, as recorded by divers.

er, *Sphoeroides spengleri*; planehead filefish, *Monacanthus hispidus*; and tomtate.

Baited blackfish traps caught moderate numbers of black sea bass and southern porgy, while the baited Antillean trap caught larger numbers of both species during the same time period (Fig. 7). The unbaited blackfish trap caught low numbers of both species and the unbaited Antillean trap caught many southern porgy and few black sea bass. Numerous small black sea bass (15-20 per trap) would swim freely through the trap mesh and actively feed on fresh bait, especially in the blackfish traps. Small individuals were not taken in final catches, thus were not included in diver counts (Fig. 7). These juveniles became less abundant with time of soak and with increase in number of larger individuals in the trap, and were not observed at unbaited traps.

Escapement, represented by a decrease in the numbers of fish in a given trap, occurred primarily during night, between the last diver observation and trap hauling (Fig. 7). The disoriented behavior of most species during trap retrieval suggests that escapement probably did not occur during that procedure. Also during the night, large numbers of southern porgy escaped from the Antillean traps, particularly unbaited traps.

Although small numbers of black sea bass escaped from unbaited Antillean traps, escapement in less than 24 hours from baited traps was minimal. The number of black sea bass in the baited Antillean trap increased during the night. With this exception, there was generally no increase in catch during the night period.

Both species actively swam upcurrent toward a freshly baited trap until entering the funnel or becoming part of the mixed species aggregation near the trap. There was much less activity near an unbaited trap, where smaller numbers of fish approached and slowly milled about all sides of the traps. Fish inside the traps, with the exception of the small free-moving black sea bass, appeared to move slower than those outside.

Intensive comparative trap studies

were made 23-25 June 1976 in Area 3 (33-35 m depth). Traps were set in groups of six with approximately 100 m between traps. Each group contained three baited blackfish traps, one baited mini-S trap and two unbaited mini-S traps. Sets were for periods of 1, 6, and 12 hours and included day and night soaks, for a total of 78 individual soaks representing 516 hours (Table 10). Bait consisted of either menhaden or round herring.

One-hour soak periods were eliminated after the first day and night sets due to time limitations. All trap catches in Area 3 were standardized to number of fish caught per hour soak per cubic meter trap volume. Standardized catches were compared to indicate most efficient use of vessel time and deck space. A one-way analysis of variance was used to compare results of nonstandardized catches between sets of trap conditions.

The results of intensive trapping trials in Area 3 differed with each combination of trap conditions (day, night, length of soak) but appeared relatively consistent within replicates (baited blackfish traps and unbaited Antillean S-traps). Conclusions should be considered preliminary due to the small number of replicates of several trap conditions (Table 10).

The Antillean traps collected a total of 13 species, the blackfish traps a total of 9 (Table 6). The five most abundant species collected in both trap types were red porgy, black sea bass, tomtate, southern porgy, and bank sea bass (a single catch of 219.3 kg, 87 individuals, of banded rudderfish, *Seriola zonata*, in an Antillean trap excluded); other species were caught in considerably lower numbers than these five (Table 6). A total of 15 species was caught in both trap types.

Baited traps of both types were more effective in catching fish than unbaited traps during short periods (<24 hours) in the inshore sponge-coral habitat. Unbaited Antillean traps caught significantly less fish (Table 10) than baited traps under all conditions ($P=0.01$), so were excluded from further comparisons. Munro et al. (1971) found that unbaited traps fished for long periods (≥7 days) caught more fish than baited traps on shallow Jamaican reefs (although baited traps caught greater weights of fish), and Wolf and Chislett (1974) report unpublished observations that unbaited traps work as well as baited traps on shallow Caribbean reefs (this may be due to the Caribbean practice of leaving noncommercial fish in the traps when reset, thus effectively baiting the trap). Our results are closer to those observed on deep Caribbean reefs by Wolf and Chislett (1974); their unbaited traps caught little or nothing, at soak lengths of less than 24 hours.

Table 10.—Number of traps fished/mean number of fish caught per trap in Area 3.

Hours of soak	Baited				Unbaited Antillean	
	Blackfish		Antillean			
	Day	Night	Day	Night	Day	Night
1	3/1.00	3/3.67	1/3.00	1/20.00	2/0.00	2/0.50
6	12/19.42	12/12.08	4/35.00[1]	4/20.75	8/0.88	8/0.38
12	3/11.00	6/15.33	1/65	2/37.00	2/1.50	4/0.75

[1]A single catch of 87 banded rudderfish was omitted from the average.

Standardized catches of black sea bass were highest in both baited trap types with 6-hour soaks during the day (Fig. 8). At night, catches of black sea bass increased to a high at the 6-hour soak in the blackfish trap but decreased from a high at 1 hour to a low at 12 hours in the Antillean trap.

Catches of red porgy were greatest in 6-hour soaks of the Antillean traps during the day. At night, catches of red porgy declined from a high at 1 hour to a low at 12 hours in the Antillean traps and remained low and relatively constant in the blackfish traps.

The largest standardized catches for all species combined were made by both trap types at night with 1-hour soak periods (Fig. 8). Baited Antillean traps made the largest single catch and the largest catch per set of conditions (night, 1-hour soak) but baited blackfish traps caught more fish under most conditions (night, 6- and 12-hour soaks; day, 1- and 6-hour soaks). During night trapping, standardized catches from both types of traps decreased from a high catch at 1 hour progressively to a low at 12 hours, while day catches of both trap types were least at 1 hour and greatest for 6 hours.

Absolute catches (not standardized) differed between trap types and soak periods. Mean number of fish caught in a baited blackfish trap varied significantly with soak length during both day and night. Mean 6-hour catches were significantly greater than 1-hour and 12-hour catches during day ($P=0.05$) while at night mean 12-hour catches were significantly greater than 1-hour and 6-hour catches. There was no difference between mean day and night catches for 1-hour sets.

The mean numbers of fish caught by baited Antillean traps could only be compared for 6-hour sets and between 6- and 12-hour sets at night because of insufficient replicates (Table 10). Although the mean catch from 6-hour sets during day was greater than the catch during night, the difference was not significant. The 12-hour set at night caught significantly greater numbers of fish than the 6-hour set at night.

The baited Antillean trap caught significantly more fish than the baited blackfish trap during each of the comparable periods (6-hour day, 6- and 12-hour night).

The two predominant fish species (black sea bass and southern porgy) of Area 1 were actively attracted to baited traps. Trapping can and should be used as a method of estimating the relative abundance of black sea bass because they are missing or relatively rare in trawl catches in these areas. A representative sample of the fish lengths in the entire local population might be obtained by trapping with a trap of 0.5-cm mesh; use of this small mesh would preclude escapement of small juveniles as observed in this study, although the

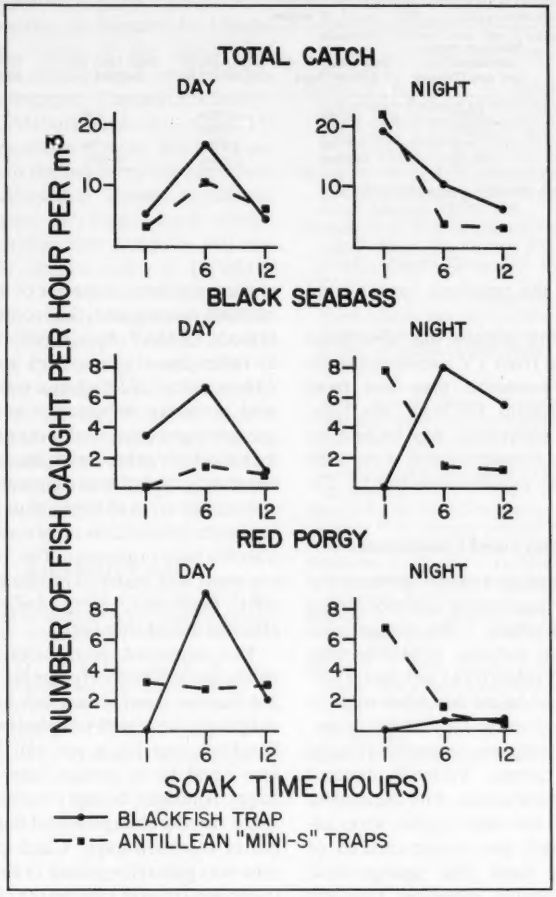

Figure 8.—Standardized catches (number of fish per hour per m^3 trap volume) of traps from Area 3.

use of smaller mesh may have effects on the catches of larger fish.

Although southern porgy were abundant in trap catches, they are also present in large numbers in trawl catches. Since the trawl catch is presently considered a more quantitative sample, results from trawl and trap catches should be compared for an extended period prior to selection of either gear for assessment of southern porgy populations.

In Area 3, traps consistently collected red porgy, which were second only to black sea bass in total weight of catch. Red porgy was collected by groundfish trawls only sporadically. The variability of trawl catches of red porgy may indicate that trap collections would provide a better estimate of relative abundance for this species. Red porgy avoid observation by most divers and remain at the outside edge of a diver's visual range (Parker[4]), thus direct observation methods may be inadequate for assessment. Comparisons of trawl catches with trap catches of the other major species collected (Table 6) suggest that relative abundance could be estimated with either a standardized trap set or trawl.

The total numbers of fish caught in both types of traps increased between the 1- and 6-hour sets, and continued to increase at the 12-hour sets, with the one exception of baited blackfish traps fished during day. However, standardized catches decreased with length of set for both trap types at night and peaked at 6 hours for both trap types during day. Trap saturation in less than 6 hours appears insignificant in stock assessment over a large habitat area, but may be great enough to account for blackfish trap fishermen's short soak periods (Rivers, 1966) in areas of large commercial concentrations.

The Antillean traps caught more fish than the blackfish traps, but standardized catches (per unit volume) were greater in the blackfish traps. This suggests that blackfish traps would provide more efficient use of limited trap storage space on survey vessels than Antillean traps. Wolf and Chislett (1974) found that a large "Z" trap (120 $feet^3$ volume) caught greater average weight of fish than a smaller "Z" trap (72 $feet^3$); however, mean catches per unit volume were identical for the two traps (0.25 pounds/$foot^3$). Munro (1974) reported that baited traps of several types fished off Jamaica caught fish in proportion to the area covered by the trap.

Trap catch information from standardized gear and soak can be used as indices of relative abundance for some species, but biomass estimates from trap catch results require several assumptions. The mean size of fish in the area must be estimated remembering the selectivity of trap and trawl collections. The habitat area effectively fished by a trap type can be estimated for some species from the visual count results of TV transects or trawl collections.

Comparison of three 24-hour baited trap sets (1 Antillean, 2 blackfish) in Area 1 with nearby TV transects (275, 276, 280, 281, 309; Table 3) permits

[4]P. Parker, Beaufort Laboratory, Southeast Fisheries Center, NMFS, NOAA, Beaufort, NC 28516. Pers. commun.

preliminary estimation of the area sampled by baited traps. Similar calibration of traps for crab stock assessment has been done by Miller (1975), who compared trap catches with biomass estimates from underwater photography transects. Mean fish density estimates from these television transects were 100 southern porgy/ha and 54 black sea bass/ha (Table 4). The Antillean trap caught 41 southern porgy and 35 black sea bass, corresponding to areas sampled of 0.41 ha and 0.65 ha, respectively. Mean catches of the two blackfish traps were 11.5 southern porgy and 9.0 black sea bass, corresponding to areas sampled of 0.12 ha and 0.17 ha, respectively. If areas sampled by each trap are standardized to unit volume of the trap, the Antillean trap sampled 0.46 ha/m^3 for southern porgy and 0.73 ha/m^3 for black sea bass, while the blackfish traps sampled 0.63 ha/m^3 for southern porgy and 0.89 ha/m^3 for black sea bass.

Similar estimates of the area sampled by the two trap types in Area 3 were made assuming that the maximum mean trawl catch values (3/4 Yankee/URI and day/night) were most representative of species abundance (Table 7). In Area 3, the highest estimate (3.06 ha) of area sampled by blackfish traps for black sea bass (Table 11) was unrealistically large due to the low mean catches of black sea bass by trawls. The low values (0.00±0.03 ha sampled) estimated for southern porgy were influenced by large mean trawl catches and relatively small mean trap catches of this species. Therefore, comparisons of trap catches with TV transect counts for black sea bass and southern porgy may give more reasonable estimates of the areas effectively fished by the traps.

Both comparisons suggest that a baited trap may sample a wider area for black sea bass than for southern porgy; this seems reasonable since black sea bass were observed to feed more actively in traps than southern porgy and took baited hooks more readily during incidental handlining on the cruise. More data are needed to confirm the validity of such observations; however, it appears that trap catches can be used to estimate biomass of selected fish species of the nearshore sponge-coral habitats.

Table 11.—Estimates of the area sampled by 6-hour trap sets for four species in Area 3 from largest mean trawl catch values.

Species	Maximum species abundance from trawl data (Table 6)	Mean catch (N=4) Antillean traps	Area sampled Antillean trap	Mean catch (N=12) blackfish traps	Area sampled blackfish trap
Tomtate	44/ha	3.75D[1]	0.09ha	1.17N[1]	0.03ha
Southern porgy	72/ha	2.00D	0.03ha	0.17D	0.00+ha
Black sea bass	3/ha	8.50N	2.83ha	9.17N	3.06ha
Red porgy	21/ha	16.00D	0.76ha	10.50D	0.50ha

[1]D = Day set max. value; N = night set max. value.

Our results suggest that abundance information from TV transects may be more representative than that from trawl collections for black sea bass, while trap collections may be best for red porgy. Southern porgy were estimated to be equally abundant by TV and trawls.

Summary and Conclusions

The sampling scheme planned for MARMAP assessment and monitoring of the groundfish of the sponge-coral habitat areas includes 10-minute tows of the 3/4 Yankee trawl and short (≤6-hour) sets of baited blackfish traps in sponge-coral areas located by reconnaissance with the vertically-directed television camera. Vertically-directed underwater television, with the camera attached to the ship's hydro wire, offered a quick and simple method of identifying sand and sponge-coral areas. Although television transects with the camera panned horizontally permitted identification and enumeration of the most abundant demersal fish species, and thus standing crop estimates, areas of bottom sampled per unit time was less than with trawling, and the necessity of using divers made the use of television more weather and depth limited than trawling. Television transect standing crop estimates were useful for comparison with trap and trawl data, and further comparative studies would be of value. Uzmann et al. (1977) suggested that a combination of visual data and trawl data may be best for assessment in canyon areas, but cost considerations may limit several alternatives (submersible surveys).

Ten-minute trawl tows sampled the greatest numbers of species of the three methods investigated, thus contributing to the MARMAP objective of community rather than single-species sampling. Although the URI high-rise trawl sampled presently important commercial species (groupers, red porgy) better than the 3/4 Yankee trawl, the 3/4 Yankee trawl sampled both a greater variety and smaller sizes of fishes, thus providing better information on juveniles and possible prey organisms. The 3/4 Yankee trawl was easier to handle than the URI high-rise, permitting more efficient use of ship time.

Two important sponge-coral habitat fishes apparently poorly sampled by the 3/4 Yankee trawl, black sea bass and red porgy, were well sampled by traps. Blackfish trap catch per unit volume was equal to or greater than that in larger Antillean S-traps; limited deck space for trap storage would thus favor use of blackfish traps. Catch per unit time was generally greater in short sets (≤6 hours) than in long sets (12 hours). At present in the South Atlantic Bight, trap data are inadequate for generating standing crop estimates of demersal fishes, because area effectively sampled is unknown, but yearly trap surveys should provide data on annual population changes. Further studies of area effectively sampled, by comparison of trap and television data, appear justified from our preliminary results and the more definitive results of Miller (1975).

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U.S. Fish Catch Up in 1978

The United States' 1978 catch of fish increased by 13.8 percent over 1977, according to preliminary figures released by the Food and Agriculture Organization of the United Nations in Rome. In 1978, U.S. fishermen landed 3,511,719 metric tons (t) of fish and shellfish. This was an increase of 426,508 t over the 1977 landings of 3,085,211 t.

The U.S. increase is in sharp contrast to the small gain in worldwide catches for the same period. In 1978, the world's total catch was 72,379,500 t, a 1.6 percent gain over the 71,212,900 t caught in 1977. Just as the United States, all major countries of the Western Hemisphere—Canada, Mexico, Peru, Chile, Argentina, Uruguay, Cuba, and Brazil—had substantial increases in catches in 1978. Islands and archipelagic nations like Greenland, Iceland, Indonesia, and Papua, New Guinea, also did exceptionally well. In most other parts of the world there were no discernible trends, except in Europe where the catches in the most important fishing countries declined sharply. The hardest hit regions were Eastern Europe and the Soviet Union.

NOAA Aids Atlantic Salmon Restoration

The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service are using the fertilized eggs of Atlantic salmon raised in the Pacific Northwest in an attempt to replenish New England's stock of the fish. This new effort will complement the large-scale program of the Fish and Wildlife Service to rehabilitate the runs of these salmon into New England waters.

During the next 10 years, NOAA's National Marine Fisheries Service and the Fish and Wildlife Service, a part of the Interior Department, anticipate shipping up to five million such eggs annually to the Northeast from Washington State.

Under the program, young Atlantic salmon from New England are being flown to the NMFS Aquaculture Experiment Station at Manchester, Wash., and raised in saltwater pens in Puget Sound. When mature, the fish are spawned and their eggs shipped to Fish and Wildlife hatcheries in New England where the fish are hatched, reared, and released into streams entering the Atlantic Ocean.

The first batch of 120,000 eggs were fertilized in November by 50 mature male salmon air shipped to Manchester from Penobscot Bay, Maine. These eggs came from 30 mature female salmon raised in Puget Sound during an earlier experiment to develop an Atlantic brood stock in the Northwest which the National Marine Fisheries Service launched at its Northwest and Alaska Fisheries Center in Seattle in 1970. These fertilized eggs were incubated in Seattle and flown to Berlin, N.H., where they will be cared for until they are large enough for liberation. Every shipment of fish and eggs is certified by a fish pathologist to assure maximum protection against the transmitting of diseases.

NOAA has found that the pen-reared salmon grow rapidly because of the moderate, year-round seawater temperatures of Puget Sound which range from 42° to 60°F (6-16°C). Seawater temperatures in New England are colder in winter and warmer in summer.

Past Federal, State, and private efforts to develop self-supporting runs of salmon in New England were relatively unsuccessful due to a lack of enough eggs and young fish to liberate. Even though streams were cleared, sources of pollution cleaned up, dams removed, and hatcheries built, adult salmon did not return to their natural streams in enough numbers to establish viable runs. The new program is expected to provide the large, dependable source of eggs needed to establish self-sustaining runs.

The Committee for Anadromous Fishery Management of the Merrimack River and the Connecticut River Policy Committee have endorsed the program. It also has gained wide support from the States involved as well as private organizations concerned with replenishing Atlantic salmon stocks.

NMFS Aquaculture Experiment Station, Manchester, Wash.

NOAA Ship *Oceanographer* Works in Chinese Waters

The first U.S. Government vessel in more than 30 years to work in Chinese waters and to visit the People's Republic of China was scheduled to arrive in Shanghai in June, according to Richard A. Frank, Administrator of the National Oceanic and Atmospheric Administration.

The NOAA ship *Oceanographer*, 303-foot flagship of NOAA's research fleet, this summer will work together with a Chinese research vessel in studies of sediment dynamics, biology, and ocean chemistry in the East China Sea, operating from Shanghai. U.S. and Chinese scientists will work aboard both vessels. Frank described the voyage as "an historic joint research venture in an area that offers unique opportunities for scientific exploration of value to both countries.

"The United States will benefit from this research," Frank said, "because this area provides a unique opportunity to study intense sedimentation in a shallow sea. The sediment discharge on the Chang Jiang River is large and the continental shelf off this estuary is one of the widest in the world. By studying the mechanisms of sedimentation in this area, we will gain an understanding of the processes—physical, chemical, and geological—that have formed sediments in our own country and worldwide. Similar processes occur off the U.S. coast, but nowhere on a scale comparable to that in the East China Sea."

This is an important outgrowth of a protocol signed in Beijing (Peking) on 8 May 1979 by NOAA Administrator Frank for the United States and Shen Zhendong, Director of the National Bureau of Oceanography, for China. "Marine sedimentation processes were a major area of activity agreed upon under the Protocol on Cooperation in the Field of Marine and Fishery Science and Technology, and this cruise will get the program off to a fitting start," said the NOAA Administrator.

Ferris Webster, NOAA Assistant Administrator for Research and Development, returned from China early this year where, during a meeting in Beijing 22-24 January, he obtained agreement for the *Oceanographer* cruise. John Milliman of the Woods Hole Oceanographic Institution, Woods Hole, Mass., will be the U.S. Scientific Project Coordinator. A team of Chinese scientists visited the United States in March to arrange the details of the joint research effort. The *Oceanographer* began its research off China in late May on a transit from Subic Bay in the Philippines, and was to depart Chinese waters in mid-July. Port calls were made in Shanghai to change scientists, compare data, calibrate instruments, and reprovision.

Owing to the extreme shallowness and gentle slope of the ocean bottom in the area, the deep-draft (18 feet) *Oceanographer* will do research on the continental shelf away from shore, and the Chinese vessel will work close in to shore and in the estuaries. The continental shelf in that area is one of the widest in the world—stretching out as much as 400 miles and including all the Yellow Sea and much of the East China Sea.

The sediment dynamics study will concentrate on the area within and bordering the Chang Jiang (Yangtze) River estuary. The Chang Jiang is the fourth largest river in the world in the quantity of sediment transported to the ocean. It is the third largest in water discharge, and is the major fresh water source in the China Sea. Great seasonal differences in both the ocean and river systems affect the interactions of sediments, water, and biological organisms. None of these processes are well understood at present, and will be closely studied by oceanographers of the two nations.

The U.S.-Chinese activity will include measuring currents and the movement of sediments, bottom profiling, and taking core samples for geological and biological purposes. A modeling program will also be initiated to help guide research in later stages of the project.

Project plans call for further cooperative work over a three-year period, culminating in a joint symposium to present work results and joint publication of the findings.

The *Oceanographer* was in the North Pacific in February studying mixing and internal-wave processes. It returned to San Diego, Calif., 11 March. The ship was to then go to Kwajalein Atoll and on to Davao, Philippines. This leg of its journey was to be devoted to looking at apparent relationships between sea-surface temperature anomalies and global climate trends. From 30 April to 21 May the research vessel was to undertake internal wave experiments in the Sulu Sea between the Philippines and Borneo, and on 24 May she left Subic Bay for Shanghai. The home port of the *Oceanographer* is Seattle, Wash.

The *Oceanographer*.

World Fishery Trade Told for 1978

The enactment of 200-mile marine zones by coastal countries has resulted in a significant increase in the international trade of fishery commodities. Over $10.5 billion worth of edible fish was imported in 1978, a 21 percent increase over the $8.8 billion imported in 1977. West European countries imported $3.8 billion and Japan $3.0 billion in 1978, a 23 and 32 percent increase over 1977 imports, respectively. The United States, the other major international seafood importer, on the other hand, bought $2.2 billion in 1978, a 7 percent increase over 1977.

Developed countries have been the major beneficiaries of the new 200-mile zones. Shipments of seafood products from developed countries totaled $6.8 billion in 1978, a 21 percent increase from the $5.6 billion exported in 1977. Most of this increase was due to expanded shipments from Canada and the United States, although both the Netherlands and Ireland also reported sharp increases.

Developing countries, on the other hand, have reported export increases which have probably not even made up for inflation. Shipments of seafood products from developing countries totaled $3.4 billion, only an 8 percent increase over 1977 shipments of $3.1 billion. Almost all of the increase was due to expanded exports from Latin American countries, primarily Uruguay, Argentina, Chile, Peru, and Mexico.

The Food and Agriculture Organization (FAO) of the United Nations has prepared a 12-page study of the world trade in fishery products for 1978. The international trade in frozen seafoods (groundfish, other finfish, tuna, shrimp, squid, and octopus), dried fish, canned fish, fish meal, and oil are described in separate sections. A copy of the report can be obtained by requesting the attachment to IFR-80/15 from NMFS Regional Statistics and Market News Offices, enclosing a self-addressed mailing label. (Source: IFR-80/15.)

CHILE FISHING LICENSE REGULATIONS OUTLINED

Chile has established a de facto procedure whereby all offshore fishing must be done by a Chilean company, but not necessarily one owned by Chilean citizens. Foreign-flag vessels are not excluded by law from obtaining licenses, but in practice such licenses have not been issued since 1977. Parallel legislation under the merchant marine laws requires 51 percent Chilean ownership (among other conditions) for vessels granted Chilean registration. A liberal foreign investment law provides for tax-free importation of the capital equipment necessary to set up fishing concerns. Tuna fishing, however, is an exception and enjoys special legal provisions which permit licensing of foreign vessels to fish in Chilean waters.

Although no specific law forbids fishing in Chilean waters by foreign-flag vessels, no fishing licenses have been granted to vessels since 1977. At present, holders of unexpired licenses are the only foreigners authorized to carry out fishing activities in national waters. (As explained herein, tuna fishing is an exception.) In recent years, the Chilean Government has hardened its de facto exclusionary policy; it is not expected to soften its stance in the future, and may legitimize it soon by appropriate legislation. Ostensibly, fishing licenses can be obtained free of charge on a vessel-by-vessel basis from the Sub-secretariat for Fisheries (Director: Roberto Verdug). To obtain a license, an applicant must indicate: 1) Name and particulars of vessel, 2) the maritime area of operations, 3) the species to be fished and the expected catch tonnage. The Sub-secretariat has the power to grant licenses without restrictions and can also stop all fishing activities (for any fish species or for a fishing area) at its discretion for environmental or any other reasons.

Tuna fishing by foreign vessels is allowed under Decree No. 130 of the Ministry of Agriculture which was issued on 20 March 1959. Some legal experts claim that this law has been abrogated, but the Sub-secretariat maintains that it is still in effect and has continued granting licenses under its powers. No change is expected in this procedure. Decree 130 provides for licenses to be granted to foreign tuna vessels under the following conditions: 1) Payment of an initial license fee of U.S. $800.00 and 2) payment of a subsequent fee of U.S.$60.00 per net registered vessel ton. The license is valid for 100 days, at the end of which it may be renewed upon payment of the $60.00 per net-registered-ton fee. There are no tax liabilities other than the license fee itself and import duties on the catch which is considered as foreign imports to Chile for customs purposes.

Decree No. 432 of the Ministry of Economy states that only factory vessels of Chilean registry may operate in the country's territorial waters. (The only exception to this rule is in the 200-mile zone around Easter Island.) The Director Del Litoral (Commandant of the Coast Guard) may, however, grant restricted licenses to "special vessels" for reasons of: 1) Transfer of technology, 2) research, and 3) the development of unexploited resources, or the unavailability of Chilean facilities. These licenses are difficult to obtain and the Direccion Del Litoral has been increasingly reluctant to grant these restricted licenses.

In general, foreign firms and individuals wishing to register and operate factory and other fishing vessels under Chilean flag must comply with the fol-

lowing: 1) Form a company domiciled in Chile; 2) Comply with the requisites of Decree Law No. 2222 which state inter alia that vessels flying the Chilean flag must have 51 percent Chilean ownership and a Chilean captain and crew (the last two requirements may be waived for the same reasons "special vessels" above are granted exemptions from flying the Chilean flag); 3) Fishing vessels over 3,600 t are exempt from customs duty while other types of vessels may be imported pursuant to a foreign investment agreement. Under special circumstances, these vessels could be relieved of value added tax and customs duties, but are subject to all the provisions of the Foreign Investment Act (Decree Law No. 600); and 4) Onshore processing plants are not affected by maritime laws and are subject to the normal foreign investment procedures and regulations. (Source: U.S. Embassy, Santiago; IFR-80/2.)

Publications

New NMFS Scientific Reports Published

The publications listed below may be obtained from either the Superintendent of Documents (address given at the end of title paragraph on affected publications) or from D822, User Services Branch, Environmental Science Information Center, NOAA, Rockville, MD 20852. Writing to the agency prior to ordering is advisable to determine availability and price, where appropriate (prices may change and prepayment is required).

NOAA Technical Report NMFS SSRF-734. High, William L., and Donald D. Worlund. "**Escape of king crab, *Paralithodes camtschatica*, from derelict pots.**" May 1979. 11 p.

Abstract

Loss of 10 percent per season of pots (traps) in the Alaskan fishery for the king crab, *Paralithodes camtschatica*, has raised the question of possible loss of crabs and fishes to the derelict, or lost, pots which continue to fish. We conducted a series of experiments during 1974 and 1975 in which tagged king crab were placed in several types of pots and returned to the bottom (soaked) for periods of 1-16 days. As controls, we released some tagged king crab in Chiniak Bay, Kodiak Island, Alaska. Tagged crab missing from the pots at time of recovery were credited with escape.

The experiments demonstrated that 92 percent of undersize and 80 percent of legal-size king crab readily escaped the derelict pots. Mortality among crab held in pots for various experiments ranged up to 12 percent. Crab that escaped within 1-4 days were recovered by commercial fishermen at about the same rate as those released in Chiniak Bay near the experiment site. However, those released after a 10- to 16-day confinement were returned at a much lower rate. Some commercially valuable fishes—such as Pacific halibut, *Hippoglossus stenolepis*—were also caught in the experimental pots.

NOAA Technical Report NMFS SSRF-738. Reid, R. N., A. B. Frame, and A. F. Draxler. "**Environmental baselines in Long Island Sound, 1972-73.**" December 1979. 31 p. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Abstract

Quasi-synoptic surveys of water column temperature, salinity, nutrients and dissolved oxygen, sediment grain sizes and organic content, and benthic macrofauna were conducted throughout Long Island Sound in July-August 1972 and April and September 1973. Temperatures were fairly uniform both vertically and horizontally except for some vertical stratification in July-August 1972. Salinities increased gradually from east to west, while depth-related differences were minor. Concentrations of all nutrients measured indicated that inputs at the western end dominated nutrient distributions for the Sound. Dissolved oxygen decreased from east to west and with increasing water temperature. Bottom dissolved oxygen values below 2 mg/liter were recorded at several stations in the western Sound in summer 1972. As a rule, sediments of deep waters in the central and western Sound consisted of silts and clays, whereas sands predominated along the Long Island shoreline and in the eastern basin. Sediments organic matter reached highest values (to 10 percent) in the westernmost Sound. Three assemblages of benthic macrofauna were identified via cluster analyses of 1972 data: A bivalve (especially *Mulinia lateralis*) dominated group in muddy, deepwater regions; a shallow sandy assemblage in which the bivalves *Spisula solidissima, Tellina agilis,* and *Ensis directus* predominated; and a third assemblage transitional in both sediment characteristics and species composition, but with increased dominance by several polychaete species. The mud-bottom and transitional fauna underwent large decreases in numbers of species and individuals from 1972 to 1973.

NOAA Technical Report NMFS SSRF-739. Davis, Clarence W. "**Bottom-water temperature trends in the Middle Atlantic Bight during spring and autumn, 1964-76.**" December 1979. 13 p.

Abstract

Annual variations of bottom-water temperatures on the continental shelf between Cape Cod and Cape Hatteras were examined for the spring and autumn from 1964 to 1976. Temperatures generally were highest since 1972 during both seasons. For waters between Cape Cod and Hudson Canyon, maximum temperatures occurred in the spring of 1976 (8.3°C) and autumn of 1972 (12.8°); between Cape Hatteras and Hudson Canyon, temperatures peaked in the spring of 1974 (9.0°C) and the autumn of 1972 (15.7°C). Minimum temperatures were in the spring of 1970 (5.1°C) and autumn of

1967 (9.7°C) and in the spring (4.6°C) and autumn (12.1°C) of 1970 in the respective areas.

Some factors that affect bottom-water temperatures, the relationship of the observed temperature variations to temperature fluctuations in other areas of the northwest Atlantic, and the effects of temperature changes on the distribution of several fish species are briefly discussed.

Reef Fishes Reviewed for the Gulf of California

"**Reef Fishes of the Sea of Cortez**," subtitled "The Rocky-Shore Fishes of the Gulf of California," has been published by John Wiley & Sons, 605 Third Avenue, NY 10016. The authors are Donald A. Thompson, Professor and Curator of Fishes, Department of Ecology and Evolutionary Biology, The University of Arizona; Lloyd T. Findley, Professor and Curator of Fishes, Escuela de Ciencias Maritimas y Alimentarias, Instituto Tecnolgico y de Estudios Superiores de Monterrey, Guaymas, Sonora, Mexico; and Alex N. Kerstitch, Research Associate, Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson.

This book is the first comprehensive volume specifically dealing with the fishes of the Gulf of California. Well written, it will be understandable to amateur naturalists and will be valued by professional marine biologists and ichthyologists as well. Natural history of 271 species of reef fishes is given, along with taxonomic data and information on the identification and distribution of each species. A brief section also discusses nonresident fishes that are frequently encountered on reefs or along rocky shores.

The volume is handsomely illustrated with both color and black and white photographs, drawings, and diagrams. Species chosen for major treatment or greater coverage were selected owing to their abundance and ecological importance to the reef community.

An introductory chapter, "The reef-fish community," discusses habitats, reef-fish diversity, and reef-fish communities in the Gulf. A second chapter, useful to amateurs, details the anatomy of a bony fish and explains taxonomic techniques. But the bulk of the book is devoted to the family and species accounts of the 271 reef fishes. Appendices, which provide a species checklist and give localities of the reef fishes illustrated, are followed by a glossary, general and specific bibliographies, and an index.

The volume is primarily based on collections and observations of reef fishes that the authors and their students and colleagues made between 1963 and 1979. Distribution of species, both inside and outside the Gulf is provided where applicable. Species accounts provide natural history data including information on habitat, depth range, feeding habits, territorial behavior, reproductive habits, physiological tolerances, etc. The 302-page volume is available from the publisher for $34.50 plus postage.

Marine Toxins and Other Bioactive Metabolites

Publication of "**Marine Toxins and Other Bioactive Marine Metabolites**," by Yoshiro Hashimoto, has been announced by the Japan Scientific Societies Press, Tokyo. The author is with the Laboratory of Marine Biochemistry, Faculty of Agriculture, The University of Tokyo. Translation into English was done by Shoji Konosu, Kanehisa Hashimoto, Yoshio Onoue, and Nobuhiro Fusetani.

This volume deals with toxic organic compounds derived from either marine or freshwater organisms. In addition to toxins, a large number of compounds with a wide spectrum of biological activity are also included. The toxins are divided into three categories: Those that cause food poisoning; those that are administered by a venom apparatus; and others. Special emphasis is placed on toxins responsible for food poisoning. The book also includes material on the histological, epidemiological, pharmacological, ecological, and biological aspects of the toxins.

The contents are arranged in four chapters. Chapter 1 defines marine toxins and research techniques, details their public health significance, and examines the exploitation of marine biochemical resources and marine toxins. Chapter 2 lists marine organisms which cause food poisoning (certain freshwater and terrestrial organisms containing related toxins are also listed); chapter 3 lists marine coelenterates, echinoderms, mollusks, and fish with toxic stings or bites. Chapter 4 provides data on such other poisonous marine organisms as algae, flagellates, sponges and coelenterates, echinoderms, mollusks, nemertines, annelids and other invertebrates, and certain fishes.

The 390-page hardbound volume is available from the Business Center for Academic Societies Japan, 20-6, Mukogaoka 1-chome, Bunkyo-ku, Tokyo 113, Japan for $46.00.

Advances in Marine Biology Published

Volume 15 of "**Advances in Marine Biology**," edited by Sir Frederick S. Russell and Sir Maurice Yonge, has been published by Academic Press, London. The book begins with a 231-page review of the biology of the small copepod Pseudocalanus by C. J. Corkett and I. A. McLaren of Dalhousie University, Halifax, Nova Scotia, Canada. The second short article by Russell briefly considers the realm of "Marine biology and human affairs."

A review of recent research on the nutritional ecology of Ctenophores is provided by M. R. Reeve and M. A. Walter of the University of Miami's School of Marine and Atmospheric Science, Miami, Fla. Two reviews of pollution and plankton round out the edition. The first, by E. D. S. Corner, of The Laboratory, Marine Biological Association, Plymouth, England, deals with petroleum hydrocarbons and related compounds. The second, by A. G. Davies, also with The Laboratory in Plymouth, reviews similarly the levels of heavy metals present in the sea. The 563-page volume is available from Academic Press, Inc. (London) Ltd., 24-28 Oval Road, London, NW1 7DX England at a cost of £31.00.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Citations" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

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Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10- inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 1700 Westlake Ave., N., Room 336, Seattle, WA 98109.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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